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ENGINEERING FACTS AND FIGURES

FOR 1865.

ENGINEERING FACTS AND FIGURES

FOR 1865.

AN

ANNUAL REGISTER OF PROGRESS IN MECHANICAL ENGINEERING AND CONSTRUCTION.

EDITED BY

ANDREW BETTS BROWN,
MECHANICAL ENGINEER.

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PREFACE.

THIS the third volume which the Publishers have had the privilege to present to the Engineering Public, embodies, as will be seen on inspection of its pages, many improvements in arrangement, and in addition, has a large accession to the number of the illustrations which were given in the preceding volumes. It is scarcely necessary, therefore, to say that every endeavour has now been, as every endeavour will hereafter be made, to render the work worthy of the notice and patronage of the members of the distinguished profession which its pages address. As the principles upon which it is based have already been, in the preceding volumes, fully stated, further reference to them is not here desiderated; it is, however, right to state, that of the high practical utility which the work claims to possess, numerous and gratifying evidences have been forwarded to the conductors. Professional engagements and other circumstances have prevented the Editor from giving that attention to the details of the work which he would have wished to have bestowed upon them; delegation, therefore, to another gentleman has been therefore necessary to secure that efficiency which he believes is attained in the present volume.

For the matter of the papers of which the volume is composed, the Editor has to acknowledge his special obligations to the following Journals published in this country, all of which are conducted with admirable ability, and contain a vast variety of valuable facts and papers. He can only regret that the limited space at his disposal has prevented him from drawing the attention of his readers to other subjects discussed in their pages:—The Engineer; the Mechanics' Magazine; the Practical Mechanics' Journal; the Engineer and Architect's Journal; the Building News; the Builder; the Chemical News; the Scientific American, published at New York; and the Transactions and Reports of the Scientific Societies and Associations.

March, 1866.

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ENGINEERING

FACTS AND FIGURES FOR 1865.

DIVISION FIRST.

BOILERS AND VESSELS FOR CONTAINING STEAM AND OTHER FLUIDS UNDER PRESSURE.

1. THE saying of that distinguished authority on matters mechanical—William Fairbairn—that the danger in the use of high pressure steam does not consist "in the intensity of pressure to which the steam may be raised, but in the character and construction of the vessel which contains the dangerous element"—may be set down as one of those truisms which one meets every day, containing a vast deal of suggestive truth, but which is often overlooked, if not altogether ignored. It contains the very pith or marrow of the whole question; yet although not deniable by any one, it is true, notwithstanding, that the principle which it involves is not accepted as the one which should dictate the practice of many to whom the manufacture of boilers is intrusted—and we may add, of those by whom they are held in daily use. Else—and the question really comes forth with power in view of these catastrophes—else how is it that the public sense of what ought to be, but unfortunately is not, is every now and then shocked by a recurrence of those accidents which result in such extensive loss of life and property? It is the saying of one who has said many good things in his day, that "self-interest is always intelligent." In the matter of the use of boilers notoriously defective in form, material, and construction, self-

interest is *not* always intelligent; for however easily employers may take the loss of life which the accidents arising from the use of boilers —and truly life, by some, is in estimation low enough—one would think that their self-interest would prompt them to avoid, by all means in their power, the loss of their property. In view, indeed, of the recklessness with which such a power, gigantic for good or evil, according as it is used or abused, is availed of in practice, it seems almost a hopeless task to endeavour to place matters on a universally right footing, either through the powers of the press, or the persuasions of science. And yet, degraded as in too many instances we have found the science or art, or call it what you will, of Boiler Engineering for long time to have been, it is consoling to know that we are moving, and in the right direction. For long left to take care of itself, under the impression, apparently, that no care was needed, boiler engineering is now demanding the attention and engrossing the cares of a large and enlightened portion of the mechanical community. We see abundant evidences around us of the truth of this, and of these evidences, this year's record of "Engineering Facts and Figures," which we are again privileged to place before the reader, and which we are about to commence, will, we trust, be a fair résumé. This résumé we shall, for the convenience of ready reference, arrange under the following heads:—SECTION FIRST, Forms of Materials, and Construction of Boilers—Theoretical and Practical Considerations affecting these. SECTION SECOND, The Appliances of Boilers and their Practical Management. SECTION THIRD, Wear and Tear of Boilers—Causes which deteriorate them. SECTION FOURTH, Explosions of Boilers. The points connected with Furnaces, and the Fuel which is consumed in them, will be found discussed under Division Second.

SECTION FIRST.

2. *Forms and Materials of Boilers—Theoretical and Practical Considerations affecting them.*—(*a*) "The Field Boiler." In par. 2, p. 3, of our volume for 1864, we give a description of the then novelty of the year, in the form of the "Harrison," or Cast-iron ere Boiler, and for the details of which we refer the reader to named above. We have this year to present a description

and illustration of a new form of boiler which is causing considerable discussion amongst engineers, and for both of which we are indebted to an article in the "Civil Engineer and Architect's Journal." The writer of this article commences by pointing out the object of a steam boiler, which in few words may be summed up by stating that the less time and the less space occupied in evaporating any given quantity of water the better. Advantageous, however, as quick evaporation may be, it is obvious that these advantages depend very much on the way in which that evaporation is carried on. They must not, for instance, be purchased at any sacrifice of fuel, of space, or of safety. After pointing out that in the Cornish, and boilers of similar class, i. e. with large internal flues, and in multitubular boilers, with small internal flues, quick economical evaporation, in the sense maintained by the writer of the paper, is not attainable. Two premises are presumed by the writer to be correct, namely, "Firstly, that we cannot use the Cornish system with its large body of inert water; and secondly, that the plan of passing the heated products of combustion in thread-like streams through the water space, as in the ordinary multitubular boiler, is also practically incorrect."

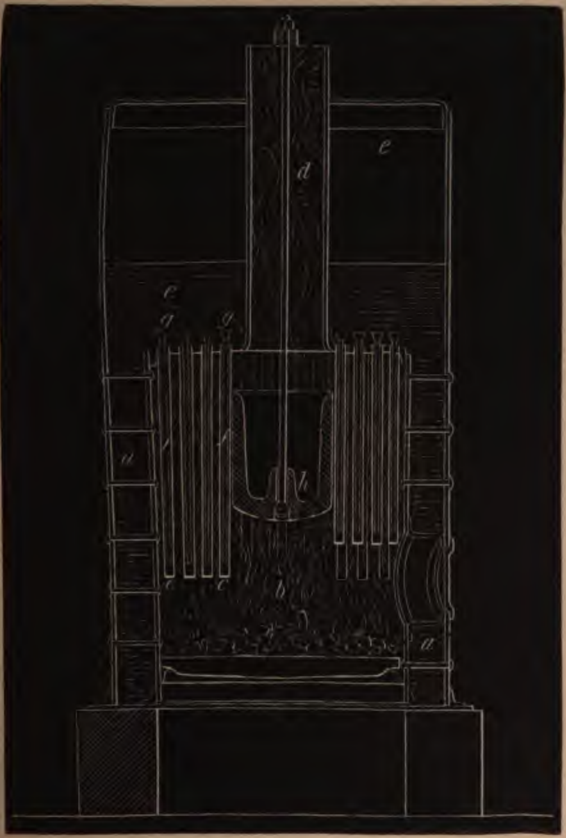
"Let us now suppose," the writer continues, "that instead of passing the products of combustion in small streams through the water, we cause the water itself to pass in like streams (and with a rapidity of flow self-proportioned to the heat whereby it is surrounded) into and through the hottest part of the furnace. The result will then be that, with slow combustion the circulation will be slow, so that the quantity of water presented to the action of the fire in any given time will be exactly suited to its heat-imparting power; and that if the rapidity and intensity of the combustion be increased, the rapidity with which the water will pass through the furnace will be proportionately increased, and this will be so even although the fire be urged to give out the greatest possible amount of heat. Hence it is evident that, as the velocity of the circulation is in all cases regulated by the heat-giving power for the time being of the furnace, it matters not whether the combustion be slow or quick, excepting that in the latter case we shall be enabled, by the greater velocity with which the streams of water pass through the furnace, to evaporate a proportionately greater quantity in the same space. Now this is precisely the principle of the boiler under notice, the practical results of which entirely corroborate the foregoing remarks, and satisfactorily prove that the principle of submitting the water, in small and rapidly circulating streams, to the most intense heat of the furnace, is the true one, and superior to any other yet introduced; as also that, in this way, almost the whole of the heat generated in the furnace (with the exception of what is necessarily employed for the purpose of maintaining a sufficient draught) may be utilised in the production of steam, and that economy of space and weight may thus be made to go hand in hand with that of fuel.

"A consideration of the construction of the Field boiler will at once show how these effects are produced, while the boiler itself is at the same time rendered safer than any other kind of boiler in existence. It should, however, be firstly mentioned, that the principle of construction adopted in the Field boiler is not only applicable to boilers for stationary purposes, but also with equal advantage to those of the marine and portable classes, and with reference to the latter class, has proved itself capable of going through the most severe work uninjured under which other boilers have required constant repair, and have never, at the best, been free from leakage. The construction of the Field boiler is this:—

"It consists of two principal parts, namely, the water and steam space, or body of the boiler, and the furnace, or chamber wherein the fuel is burnt. For stationary purposes the boiler is made cylindrical in form, with an annular water-space *a*, surrounding the furnace *b*, as shown in Fig. 1, but the form may be readily varied and adapted as required to suit any peculiarities of circumstance or position, whether for land or marine purposes. In the case of the cylindrical vertical boiler referred to a number of tubes *c*, placed annularly around a flue tube *d*, passing upward through the boiler, hang down or are pendant from the underside of the water and steam space *e*, into the furnace *b*.

"These tubes (in Fig. 2 an enlarged tube is illustrated) are open at their upper ends into the water-space, and being closed at their lower ends are consequently (when the boiler is in readiness for starting) entirely filled with water, the top level of which is some inches above their upper ends. Within each of these

Fig. 1.



tubes is freely suspended, by means of feathers x, a smaller tube f, open at both ends, the upper end of which rises above the level of the upper end of the outer tube c, but is short of reaching to the bottom of it. The tops of these inner tubes are provided with trumpet or funnel shaped mouths or deflectors g, which, as will be seen, *perform* an important part in the action of the

Fig. 2.

boiler. A baffle-plate or cylinder *h*, suspended beneath the opening into the flue tube *d*, which passes upwards through the boiler, prevents any portion of the heat of the furnace from passing away without having firstly enveloped and become almost entirely absorbed by the pendant tubes and water circulating within them."

After describing the arrangements of boiler used for marine and steam fire engines, the writer thus concludes his paper:—"A consideration of what takes place in the working of the Field boiler will at once clearly show why it should, in all cases, contrast favourably with other boilers employed under similar circumstances. Thus, taking for example the size of stationary boiler known as 80-horse, but which will, in reality, work with ease up to 120 horse-power, the outer diameter of this boiler is 6 ft. 6 in., and its height 8 ft. 8 in. It contains 490 square feet of tube surface, the outer tubes being 2 inches in internal and $2\frac{1}{4}$ inches in external diameter; and the inner 1 inch in diameter. Now, upon lighting the fire the water in these tubes immediately commences to circulate every increment of heat, however trifling, added to the water contained in the annular spaces, between the inner and outer tubes, lessening its specific gravity, and causing it to ascend, and cold water to consequently descend the inner tubes to supply its place. This action goes on increasing gradually in rapidity until ebullition commences, at which time the velocity of flow is increased enormously, owing to the great difference between the specific gravity of the mixed water and steam *ascending* in the annular spaces, and that of the solid water *descending the inner* tubes.

"Taking the velocity of flow down the inner tubes at 10 feet per second, and the number of tubes at 289, we shall have a quantity of water equal to about 96 gallons passing down into the furnace, and being submitted to its most intense action in every second of time. Moreover, owing to the principle of action of the tubes, the water so submitted necessarily belongs to the less heated portion of the contents of the boiler, and consequently possesses the greatest capacity for heat. Now when we consider that an amount of water equal to the entire average contents of the boiler is thus passed into the furnace, with the intervention of only one-eighth of an inch of metal between itself and the fire, in every six seconds of time, some idea may formed of the immense rapidity with which the heat of the furnace may be passed into the water; which may be further strengthened by reflection on the well-known fact, that if it be attempted to harden a tolerably large piece of steel by plunging it when hot vertically into cold water, and holding it motionless in that position, the attempt will prove a failure, inasmuch as the water will fail to carry off the heat from the steel with sufficient rapidity to effect the hardening, but if, instead of holding the steel motionless as described, we move it more or less rapidly from side to side through the water, the hardening will be at once effected. Now, this is precisely the difference between the ordinary kinds of boiler and the one which forms the subject of this paper. In each case we have on the one hand a mass of water subjected to heat, and unable to change its position with sufficient rapidity to absorb the heat presented to it; and on the other, a constantly changing surface of fluid, carrying off the heat from the metal with great rapidity, and in each case effecting the object desired.

"Here, then, is one very obvious reason for the economical results achieved by these boilers, even under circumstances which might seem to put economy out of the question, the fact simply being that, in ordinary boilers, the circulation, left to shift for itself, has great difficulty in becoming of a decided character in any direction, so that the water instead of taking off, or as it were ft., expressed, rushing off with the heat from the metal 27 cwt. hangs about it, and with comparative slowness
The consequence is that much of the he power, capable of doing by, the flues instead of into the water × 7 ft. 2 in. high = area

fore remarked, that slow combustion with ordinary boilers necessarily shows to better advantage than quick. It is important in discussing the merits of any boiler to advert to the difficulties, if any, likely to arise from the deposit on its surface of these troublesome matters, the sulphates and carbonates of lime or such other compounds of them as are usually thrown down in the form of a hard scaly incrustation. It is well known that such deposits are encouraged by sluggish circulation, and that where the circulation is most feeble, as well as in the neighbourhood of the feed pipe where the water first enters the boiler, the deposit is usually thicker than at any other places. Bearing this in view, we are naturally led to expect that the effect of very rapid and constant circulation will be to prevent deposit in the channels wherein such circulation takes place, and are therefore scarcely surprised to find that the tubes of boilers of steam fire-engines constructed upon the Field principle, and worked almost daily for two years, have remained entirely free from deposit.

"It may be that some small part of this remarkable result is due to the continual changes of water, with which, from the nature of their duties, these boilers are worked, but assuredly, if that be so, the part borne by these changes in preventing incrustation is very small indeed. But allowing that continual change of water has some appreciable influence in the matter, stationary boilers on the Field system now at work show that with the most ordinary precautions there is practically no incrustation. The writer was present lately at the opening of one of these boilers for the usual quarterly examination, and is enabled to state that there was no hard or scaly deposit whatever. At the bottom of the water-space there was a light-coloured mud, which, when dried, proved to be an impalpable powder, consisting doubtless of the matters which, in ordinary cases, are deposited in boilers in the form of hard incrustation, but which, in this case, had been kept in mechanical suspension until finally thrown down into the water-space as described. The precautions which had been taken in this instance, and which were so thoroughly efficient, were of the most simple character, and consisted, firstly, in the employment of an inexpensive water heater, whereby some of the calcareons matters contained in the water were thrown down previous to its entrance *into the boiler;* and secondly, in the use in the water of a trifling quantity of composition, known as Buck's, and consisting apparently, chiefly of soda, which seemingly had the effect of completing whatever was left undone by the heater.

In reply to a correspondent in the pages of the Mechanics' Magazine, who wished some practical information as to dimensions, weight, &c., &c., of boilers of this class of given power; the inventor, Mr. Edmund Field, Chandos Chambers, Adelphi, London, addressed to the same Journal the following letter:—

"I beg to say that boilers on my principle applied to the steam fire-engines manufactured by Messrs. Merryweather and Sons, are of the following general dimensions and weights, and have done actual useful work, and held their steam thoroughly well up to and even beyond the powers named.

"A boiler, the outer diameter of which is 2 ft. 4½ in., and its height 3 ft. 9 in., the area of the fire-grate being 2·6 square ft., and that of the tube surface 54·5 square ft., has worked continuously up to 20 horse-power. The weight of this boiler is about 7 cwt., and the consumption of fuel 1 cwt. per hour.

"Another, having an outer diameter of 3 ft. 6 in., and height of 5 ft., area of fire-grate 7 square ft., tube-heating surface 192·5 square ft., and weighing about 15 cwt., has given an effective power of 68 horses, with a consumption of less than 3 cwt. of fuel per hour; and has shown itself capable of continuing it without losing pressure, for any length of time.

"For stationary purposes where weight is of less importance, I prefer to employ boilers of a more roomy construction, in which, although a longer time is occupied in getting up steam than in the class of boilers above referred to, there is much less trouble in stoking. In fact, the trouble in this respect is less with these than with boilers of the Cornish construction, while the ground space they occupy is only about one-sixth of that required for the Cornish. Thus, a stationary boiler capable of doing, with steady working, about 15 horse-power, is 3 ft. 8½ in. diameter × 5 ft. 8 in. high, its area of fire-grate being 5 square ft., tube-heating surface 60 square ft., and weight about 27 cwt. This is nominally a 10 horse-power boiler.

"The dimensions of a nominal 20 horse-power, capable of doing about 30 horses' work, are 4 ft. diameter × 7 ft. 2 in. high = area of fire-grate about 7 square ft. = tube-heating surface 121 square ft., and weight about 42 cwt.

"A nominal 40 horse-power is 4 ft. 10 in. diameter × 8 ft. 6 in. high; area of fire-grate about 10 square ft., tube-heating surface 240 square ft., and weight about 3 tons.

A nominal 80 horse-power is 6 ft. 4½ in. diameter × 8 ft. 8 in. high, area of fire-grate about 21 square ft., tube-heating surface 480 square ft., and weight about 4 tons.

"Stationary boilers of this class are evaporating over 10 lbs. water for 1 lb. of fuel."

And in the same Journal, under date of July 14th, 1865, a leading article is given on "The Field Boiler," in which there are some very interesting details connected with its practical working. The writer commences by pointing out the advantages and disadvantages of the two great classes of boilers now chiefly in use—namely, the double flue and the "multitubular" boiler. The former, he says, is probably "unequalled by any of the class to which it belongs for simplicity and effectiveness," but it takes up much space, and where space cannot be had another form is desiderated. Here comes into use the "multitubular boiler," which is comparatively safe, or rather, in the language of the writer, possesses a perfect immunity in respect of violent explosions, but this boiler has its defects, it is expensive, and it does not afford the means to allow the water to circulate freely and to absorb all the heat generated by the combustion of the fuel. A field—no pun is intended good reader—is thus open for a boiler which shall possess all the advantages but none of the disadvantages of these two boilers, and this is apparently taken well up and practically occupied by the "Field" boiler, about which the writer of the leader above referred to thus discourses, and which, he says, he believes has secured more effectively than any other form yet introduced, all the advantages aimed at by its inventor:—"The rapidity," he says, "with which it generates steam has just received another practical illustration in the steam fire-engine competition at Cologne, the report of which appeared in our last number. Messrs. Merryweather's engine, which carried the first prize, was fitted with a 'Field' boiler, and raised steam from cold water to a pressure of 100 lbs. per square inch in 7 min. and 28 sec. from *the time of lighting* the fire.

"It will, doubtless, be remembered that the 'Field' boiler was applied, in the first instance, to steam fire-engines; but, as it was considered to possess many advantages which would render it valuable for other uses, steps were taken to test its efficiency for stationary purposes, and the result proved satisfactory in every respect. By no means the least important benefit derived from the adoption of this system, is the great saving effected in the space occupied, the dimensions of a steady working 80 nominal horse-power 'Field' boiler, including furnace, being only 6 ft. 6 in. diameter, by 8 ft. 8 in. high. Then there is the further and equally important question of safety already referred to, and which is certainly one of the first considerations in putting down a new boiler, especially in densely populated localities. Upon this point we have no hesitation in stating our conviction that the system under notice is the safest form of steam generator yet introduced. In the event of shortness of water, the worst that can happen is the burning of some of the tubes, which, in fact, serve as fusible plugs, so that the fire is extinguished without further damage. This was actually proved, in a case of culpable neglect on the part of an attendant, under circumstances which must have resulted in a disastrous explosion had the boiler employed been a Cornish instead of a 'Field.' As it was, the main body or shell and the tube plate received no injury whatever, and the damaged tubes having been renewed, the boiler was very shortly again at work. Indeed, the facility with which the tubes may be renewed is remarkable, and constitutes another important feature in the boiler. It should also be mentioned that leakage is effectually prevented in consequence of the entire absence of unequal expansion and contraction.

"In some climates boilers are especially subjected to the effects of frost; under these circumstances it might be inferred that the freezing of the water in the tubes of the 'Field' boiler would be liable to cause them to burst. This, however, is found not to be the case. Tubes, of extra light make, and filled with water, have been purposely frozen and thawed four times in succession, so that the water throughout their entire length was on each occasion completely solidified. The result was simply that the inner tube was, for the time being, slightly raised, and immediately upon the ice being thawed it fell again into its proper position. In consumption of fuel, the 'Field' boiler is found to be very economical, a fact mainly due to the rapid circulation of the water through the hottest part of the fire. The combustion attainable with water tubes pendent into the fire is far more perfect than in the case of boilers constructed according to the ordinary tubular systems. The peculiar arrangement of the 'Field' boiler also enables the stoking to be more easily effected than is the case with most other steam generators. It has been advanced by some that the deposit of incrustation upon the tubes would, in many cases, form a serious obstacle to the adoption of this system of boiler. The truth is, however, that some of these boilers have been severely tested in steam fire-engines, and found to be entirely free from deposit after over two years' constant use. In the case of a stationary boiler recently opened for quarterly examination it was found as clean and free from hard or scaly incrustation as on the day it was first worked. The only deposit found was at the bottom of the water casing surrounding the furnace, where it lay in the form of a light-coloured mud. On being dried this mud or paste resolved itself into a number of disintegrated particles, doubtless those which enter into the composition of the substances that ordinarily constitute the hard incrustation on the internal surfaces of boilers. But there is nothing particularly wonderful in this when the principle upon which the boiler is constructed is taken into consideration. From observation of the action of the 'Field' boiler, as illustrated in a glass model of working dimensions, we were enabled to see that all extraneous matters were carried up by the circulation in the tubes, and thrown to the bottom of the water casing. From thence they may be blown out through a cock in the ordinary manner, and this was doubtless the case with the substances to which we have just referred.

"It may be as well to note here the practical performance of the 'Field' boiler, from which its merits will be clearly seen. The example taken is an 80 nominal horse power stationary boiler, the dimensions of which, as already stated, are 6 ft. 6 ins. diameter by 8 ft. 8 ins. high, no brickwork being required for setting except in the ash-pit. The total area of heating surface is about 568 square feet, the external tube surface presenting 490, and *the fire box 78 square* feet. The fire-grate area is 22 square feet. The weight of fuel burned on each square foot of grate is about 20 lbs. per hour. About 18 cubic feet of water are evaporated from the initial temperature by 112 lbs. of fuel, which is about 10 lbs. of water for each pound of fuel burnt. The number of cubic feet of water evaporated per hour from initial temperature is 70·4. There are 8 square feet of heating surface for each cubic foot of water evaporated per hour, and the number of square feet of heating surface for each square foot of grate is 26. The temperature of the products of combustion escaping from the chimney rarely exceeds 600 degrees, although the temperature over the fire is upwards of 3,000 degs., this fact shows how efficiently the boiler absorbs the heat from the fire. Based upon the tried practical working of the principle, the conclusions at which we inevitably arrive are, that the 'Field' boiler supplies the long-felt want of a compact, inexpensive, economical, safe, and thoroughly efficient steam generator. If anything were wanted to remove any ideality that might appear to attach to this boiler, it is supplied in the fact of its appreciation by practical men, as evidenced by a considerable number—some of large power—being at present in course of construction in this country and abroad for stationary and other purposes."

3. In last paragraph allusion has been made to the advantages, or presumed advantages, of *tubular boilers*—we say presumed, for the question of tubular, as against other forms of boiler, is one of the "vexed questions" with which the practice and the science of engineering abounds. The reader desirous to have a resumé of what has been said on the subject, will find papers bearing upon it in the volume of "Engineering Facts and Figures for 1864," in par. 4, p. 15. We supplement this by an abstract of a paper entitled "Facts and Fallacies as to Tubular Boilers," which has been given in the Practical Mechanics' Journal, under date Feb. 1st, 1865, and which is in fact a review of a pamphlet by Mr. C. W. Williams, published by Spon, London, entitled, "On the Steam Generating Power of Marine and Locomotive Boilers." In an early part of the work, Mr. Williams, in a brief but important passage, runs counter to a very generally received opinion as to the heating value or capacity of tubes. This opinion has generally been favourable, indeed when introduced by Stephenson, they were at once accepted as the thing which was es-

sential to that rapid raising of steam upon which the best qualities of the locomotive depended. If the opinion of Mr. Williams is correct, it will appear that engineers have been mistaken in their estimate of the value of tubes, and that they must look to other parts of the boiler as those which dictate its steam-raising value. The following is the passage alluded to, and the comments of the editor of the "Practical Mechanics' Journal" thereon:—

"'It will doubtless hereafter," says Mr. Williams, "be a matter of special wonder, when the construction of boilers shall have been perfected, to find that for thirty-four years, since Stephenson's *Rocket* won the prize for the locomotive, we have been following an *ignis fatuus*—the so-called heating surface of tubes; and that so far from that surface being the measure of the heat-transmitting and evaporative power, it may in fact be altogether omitted in our calculations, and for the measure of that power we shall have to look to a different part of the boiler—a portion hitherto absolutely unnoticed and unappreciated by engineers. The experiments and proofs hereafter detailed fully establish this fact beyond question.'

"So far," says the reviewer, "the statement is that the tubes of tubular boilers (locomotive or marine) are, as a means of conveying the heat of the products of the burnt fuel to the water, absolutely valueless.

"The next paragraph surpasses our comprehension, as to any distinct idea it conveys.

"'Of the tube internal surface, as regards its heat-transmitting and steam-generating property, we may, as will hereafter be shown, on the authority of the late Mr. Dewrance and Mr. Hick of Bolton, estimate its efficiency in comparison with that of the furnace or fire-box plates at but one-tenth of the gross nominal surface it presents, where the tubes are not more than six feet long. My own numerous experiments and observations fully bear out this statement.' 'Again, when the tubes are ten feet long and upwards, we will not err much if, with the exception of the first *twelve inches*, we leave them altogether out of our calculation, and regard them as mere conduits for conveying the heated products of combustion to the chimney.'

"So then, with tubes of six feet long, ten super. feet of tube is equal to one of fire box; but tubes of any greater length, however *great* their total surface, we may consider as worth nothing except the first foot of their length, and leave all the rest out of calculation altogether!

"So far for the *ignis fatuus* that engineers have been foolishly relying upon for thirty-four years as having something to do with the steam raised in locomotives, &c.—such is their sin of commission, according to Mr. Williams. Let us now come to their sin of omission—'the portion of the boiler which has been absolutely unnoticed and unappreciated by engineers.'

"Here we have it. 'Against the insufficiency of the tubes, as heat transmitters and steam generators, we have the hitherto neglected surface of the *face plate*, presenting a face to the direct action of the hot current of the furnace. Assuming the orifices of the tubes occupy one-fourth of the gross area of the face plate, the practical heat-transmitting portion will be the remaining three-fourths.

"'Hitherto the face place has been regarded as a a mere mechanical contrivance by which the tubes were held in their places, for preserving certain distances between them to enable the water to surround them.

"'Strange to say, no idea whatever appears to have been entertained that the face plates had any heat-transmitting or steam generative property *of their own*.'

"To many of our readers the term *face plate* will be new and without a distinct meaning. We may therefore here say, that the author's *face plate* means that side of the fire box of a boiler on the locomotive construction through which one end of the tubes passes.

"In Mr. Williams' *strict* sense it is only that portion of the plate forming this side of the interior of the fire box which is not cut out by the perforations for the ends of the tubes. It is, therefore, the unperforated surface of the tube plate of the fire box. We may therefore at once dispose of the sin of omission charged against locomotive and other engineers by declaring it simply a mare's nest.

"It is not a fact that *any part of the interior surface* of fire box in locomotive boilers has been unnoticed and unappreciated by engineers. We could point to scores of examples, were it necessary so to support the universal cognizance of all those engaged in proportioning such boilers, proving that all parts of the interior of the fire box, every square inch of its surface, is and always has been habitually taken into calculation and its effect allowed for; and hence this tube plate, or *face plate*, as Mr. Williams is pleased to call it, as a matter of course, included.

"Although he does not say so in words, Mr. Williams is obviously of opinion that this *face plate* does nearly all the work of the whole fire box; or, to be strict, so as to avoid injustice, he distinctly infers that each square foot of interior surface of this face plate (at a given level in the fire) is vastly more effective than any equal area of any other of the three sides of the fire box, or of its roof.

"'We here at once recognise the cause of the great steam generative power of the *single face plate* in each locomotive, namely, the almost electric rapidity of the draught in the chimney, producing a correspondent increase in the force with which the heated current strikes that plate.'"

After drawing attention to what the writer of the notice calls "fallacies" respecting the tubular boiler as propounded by Mr. Williams—he thus proceeds to detail what we may call the "facts" respecting them. "From at least the year 1834, if not earlier, the fact was clearly ascertained and recognised that unit for unit of surface, the fire box was greatly more efficient in passing heat into the water than the tubes. It is so for many reasons, mainly because the receptive surfaces of the fire box are, as respects *radiation* from the incandescent fuel, much *nearer* to particles at the highest temperature than any other part of the boiler, and the effect of radiation is greater inversely as the *square of the distance*, and as respects *conduction*, because the plates are here in actual contact with white hot coke.

"It has also never admitted of a question, on the part of any competent engineer, that as respects *convection*, each square inch of the various parts of the interior of the fire box is more effective, in proportion as a larger volume of gases, heated to a given temperature, passes it by or reaches it in whatever direction in a given time. From this last it is no doubt true, that all that part of the fire box towards which the heated gases of the fire pass in order to enter the tubes, must have more heat brought to them in a given time than to the opposite parts nearer the fire *door*. But that is all, and does not specially or solely apply to the tube plate (or face plate of Mr. Williams); it is equally true, *pro tanto*, of the roof of the fire box.

"To jump to the conclusion from this, that the tube plate does all or nearly the whole of the work of the whole interior of the fire box, is simply nonsense. To endeavour to sustain such a notion by misinterpreted experiments and ill-understood physics, is to indicate an incapacity for dealing with such questions at all.

"The comparative small efficiency of the tubes, again, has been for years fully recognised and understood. It mainly arises from the facts, first, that the temperature of the particles of the radiating streams of heated gases swept through them is greatly below that of those particles while in the fire box (where they are robbed of much of their heat); and, secondly, that the draught is obliged to be so sharp, in order to maintain the high temperature of the fire, that there is not *time* enough during the transit through tubes of ordinary length for the gases to radiate all or even the greater part of their heat.

"This is proved by the tremendous temperature of the smoke box and even the top of the funnel of every locomotive; and, to any sane man, this fact is an argument cogent and inexpugnable for lengthening out the tubes, so as with the same velocity of draught to give *more time* for radiation within the tubes.

"And here comes in the second and most extraordinary error—namely, that only the first few inches of the tubes are of any use whatever, and that in place of lengthening we should shorten them.

"To put in its true light this fallacy, we need do no more than reproduce here Mr. Williams' own first experiment. He had a boiler constructed in which a *fasciculus* of tubes 5 feet in total length was separated by plates at intervals, so that, as he says, 'the heat-transmitting value of each lineal foot of the tube would be indicated.' The compartment next to the *face plate* was only one inch in length, the second was 10 inches in length, and the four subsequent ones were 12 inches in length each. After three hours' work, the following quantities of water had been evaporated—from

	Lbs.	Oz.
Compartment No. 1 (1 inch long) . .	2	14
Do. No. 2 (10 ,,) . .	2	15

Compartment No. 3 (10 inches long)	1	14
Do. No. 4 (12 ,,)	1	6
Do. No. 5 (12 ,,)	1	2
Do. No. 6 (12 ,,)	1	1

We take it that every one will see that the first compartment of 1 inch long is in reality not that of an inch of tubes only, but of the face plate or tube plate surface also. In fact, the heat taken up by the relatively large mass of metal in the tube plate next the fire is rapidly given up to the water in contact with it and the first inch of tube. And were it worth while to expend space in further quotation we have proof in the facts given how much, in this first compartment the action of tube and tube plate are confounded.

"We shall pass by also, what most persons will perceive, that horizontal tubes thus diaphragmed off into a number of separate chambers are no longer in the same, or in as favourable a position, as in an ordinary boiler where the *water is free to circulate* in all directions, and to sweep *along* the tubes from the cooler to their hotter end, in the *reverse direction* to the current of heated gases passing through them."

4. *The Harrison Boiler.*—In par. 2, p. 3, of our volume for 1864, we gave a detailed description of this form of boiler, in which the use of cast-iron spheres is the distinguishing feature. Of the strength of these we offered a few remarks; and we now supplement them by information communicated to the Editor of the "Scientific American," by the inventor, who resides in, and is, we believe, a native of, America. "I wish to say a word in regard to the *strength* of this boiler. In making many experiments to test the bursting strength of the spheres under hydraulic pressure, no sound casting ever gave way under *fifteen hundred pounds* to the square inch; it was not unusual for them to resist *two thousand pounds*, and this, too, when made of iron of no greater strength than the best brands of Scotch pig metal. In a practical experience of several years with boilers varying from 5 to 200 horse power, explosions have never happened under any circumstances. Extreme pressure will open its joints before any thing gives way, thus making each joint a safety valve. A cracked sphere may produce a leak, but a boiler under pressure *has never been suddenly* emptied from such a cause. Instances

have once or twice occurred where a cracked sphere has been continued for some time after the fracture was discovered, with no troublesome consequences from the leakage, and no necessity for instant repairs.

"There have been but four fractures of spheres in all the boilers mentioned in the advertisement now in your journal, and in every case these could be fairly traced to special causes not connected with pressure. In my experience with this boiler, several have been *burnt*, or, in other words, rendered unfit for service for the moment by overheating after the water had fallen too low. The result in such case is obvious; spheres with no water inside and intense heat outside, are soon heated to redness and warped so much that the integrity of the joints is destroyed, causing the boiler at the injured parts to leak badly, but nothing like an explosion occurs. With great facility and little cost of time or money, the injured parts, in such a case, can be taken out and replaced by new ones, without even the use of highly-skilled workmen, after which the boiler is as good as before the accident. Some of these boilers are working daily at 180 pounds pressure to the square inch; and a good evidence of their value is shown in the fact that several parties, who have used the boiler longest in this country, have already in use, or have sent me orders for, a second one.

"With this boiler on our Western steamboats, to which it can be easily adapted, such wholesale destruction of human life as took place on the *Sultana* a few days ago, *cannot possibly occur.*"

5. *Rotatory Boiler.*—This—which is the invention of Mr. Henry Brown of St. Petersburg—takes us in quite a new direction in the novelties of steam boilers. According to an article in the "Practical Mechanics' Journal"—under date Oct. 1st, 1865—and which is illustrated by a plate, the main object aimed at by the inventor in bringing out this novel form of boiler is "the augmenting of the heating furnace, economizing fuel, and superheating or drying of the steam. In this boiler no stays are required, as from the peculiarity of its construction it forms its own stays, and is perhaps the strongest shape that can be given to a boiler, whilst it occupies a small space in comparison with boilers of other constructions and of equal power. The boiler (A) is of a cylindrical form, with spherical ends. It is inclosed

in a metal casing (B), which is lined with fire-bricks at the bottom part of the casing, and under the boilers are placed two furnaces, the furnace doors (C C), (of which there are four), are placed on one side of the casing. Between the boiler and the brick casing there is left a space for enabling the flames and heat from the furnaces to play entirely round the boiler. The boiler is hung on two cast-iron hollow necks (D D), each neck having a ring (E), keyed on to it, and turned true, and on these rings the boiler revolves. The rings (E E) work in chairs (F F), which rest on brackets (G G), fastened to each end of the outer casing (D). The ring (E), at the end by which the boiler is rotated has a toothed rim (E^1), cast on it which projects beyond the chair. Into this tooth rim or worm wheel an endless screw (F^1) works, the shaft of which is supported in bearings attached to the upper gland of the chair; this shaft is to be driven by a small engine that is required for feeding the boiler. Through one of the necks (D) passes a tube (H), which forms the flue by which the smoke passes off to the chimney (I). In the neck at the opposite end of the boiler is placed the steam pipe (J), which passes through a stuffing box in the neck. That part of the pipe which passes through the stuffing box is enlarged, and the steam channel placed eccentrically in it, so as to leave room for placing the feed pipe (K), under the steam pipe. Inside the boiler the steam pipe is carried up towards the top, and the feed pipe towards the bottom of the boiler. Through the centre of the steam pipe, and through a stuffing box is passed a small rod (*a*), fitted with a lever (*b*), on the end inside the boiler, to which is attached a hollow metal float (*c*), resting on the surface of the water in the boiler. To the other end of the rod outside the boiler is fitted a lever (*d*), with pointer and index (*e*). As the water in the boiler rises or falls so will the float, and therefore the position of the handle outside will show the height of water in the boiler. Should the rod stick or work tight in the stuffing-box, by turning the handle (*d*), the float will be pressed into the water so that the attendant can feel the surface of it in the boiler. To the end of the steam pipe outside the boiler is fitted a vertical pipe (L), which has in the middle of its length an eye (*l*), accurately bored out to fit the turned end of the steam pipe (J). The *metal of the eye* is cut through or split on one side, and the eye of the vertical pipe (L), is slipped on to the steam pipe (J), two cramps or clips being placed on the eye of the vertical pipe (L), which are screwed up by four bolts, by which the steam pipe (J) is clipped fast. The lower end of the vertical pipe (L) is bolted to a flange projecting from the chair (F), above referred to, and keeps the steam pipe (J) from turning round as the boiler revolves. An aperture is made in the steam pipe (J), to correspond with the aperture in the vertical pipe (L), for the steam to pass. On the top end of the vertical pipe (L), are placed two safety valves (M M), and a neck (N) is provided, to which a pipe is to be fitted for carrying the steam to the engine. On the vertical pipe (L), the steam pressure gauges can be fitted. The top and bottom parts of the chairs (F), in which the boiler revolves have a flange cast on them, which is bolted to the casing to prevent any cold air entering through the space that is left round the necks (D) on the boiler. The chairs are cast hollow, and water flows through them by means of the pipes (d' d'), to keep them cool. At the smoke end of the boiler, between the chair and the chimney, is placed a damper (O), the frame of which is fastened both to the chimney and chair.

"The top of the outside casing has several openings (P P), which are closed by caps hung by levers to a shaft (R), which runs along the top of the casing, supported by brackets fastened to the casing. One of the levers is made with a long arm to which is hung a chain or rod, by which the caps are lifted off the openings. The use of these openings is to prevent the top part of the boiler being overheated, should the revolution of the boiler be arrested for a time. By lifting the caps cold air will rush on to the top part of the boiler and cool it down; it will also check the draft of the chimney, and damp the fire on the grate. When the boiler is at work the openings are closed, the caps being made tight by means of a sand joint. The top part of the casing takes off from the lower part, should the boiler require to be examined; there being an angle iron frame round the two halves of the casing, by which they are screwed together.

"The inside of the cylindrical part of the boiler throughout the greater portion of its length is divided into compartments by radial plates bent into a U-shape. Of these divisions there may be any number; in the *drawing* seven of the mare shown. The

U-shaped plates are placed radially inside the shell, and between each arm of the U is left a small space (*h h h*). The shell of the boiler is cut through to correspond with these spaces (*h*), which form slots running the length of the cylindrical part of the boiler. The lower part of the U-bent plates where they meet together forms a hollow space in the centre of the boiler; this and the small spaces (*h*), above referred to, constitute the flues of the boiler, by which the smoke passes off to the chimney.

"The upper arms of the U-plates and their ends are flanged, the flanges of the arms are riveted to the outside shell of the boiler, and the end flanges have plates riveted to them, which close up the small narrow spaces (*h*), between the arms of the U-plates.

"The hollow part in the centre of the boiler is closed at one end by a plate, and opens at the other end by the tube (H), into the chimney. The flat surfaces of the U-bent plates are sunk into cups (*g g*), of which there are two on the radial and five on the longitudinal length of the plate. These cups are sunk to a depth equal to half the space (*h*), between the plates which form the radial flues. Thus when the plates are all fitted together in their places, the bottom of one cup rests on the inverted bottom of the one opposite, the cup so placed serving instead of stays to support the pressure of the steam. The spaces (*i i*) between the radial divisions are occupied by steam and water, the level of which latter should not be higher than the centre of the boiler, but may be lower.

"The ends of the U-plates being flanged, as they dip and rise out of the water they will retain a quantity of water equal to the depth of the flange. As the plates rise into the vertical position, this water will run off one plate on to the opposite one. This will prevent the plates being burnt whilst they are out of the water, and the water on these plates will be flashed into steam, which coming in contact with the heated plates will become dried and superheated."

6. *On the various forms of Boilers*, the "Mechanics' Magazine," under date Feb. 24th, 1865, has a leading article, from which we take the following extracts. After referring to the "*waggon boiler*," generally used in the early days of the steam engine, and of which the writer remarks, that so far as capacity

is concerned, "we have not at the present time its superior in shape," he proceeds to describe the cylindrical boiler with egg ends, the introduction of which was, he says, a step in the right direction, so far as strength was concerned. The writer then passes on to the internal flued Cornish boiler with flat ends; characterising this as "the best of its class for general purposes." On the question of flat, as against semicircular, or, as we should say, semi-spherical ends, the following remarks are given:—

"Those of the flat shape admit of more heating surface, and the curved ends lessen the capacity of the boiler in a given length and diameter. There is, however, no disputing its superior strength to that of the flat kind. The construction of cylindrical boilers is a subject of the highest importance. The stays for strengthening the ends are often improperly situated, particularly when angle or T iron is used. In no case whatever should the end stays be connected to the internal flue or flues. Such a practice is conducive to the fact of strengthening one portion at the cost of weakening the other. The ends, if properly stayed, should be connected by rods, one, two, or three in number, according to the area of the portion above the flue or flues. In cases where long and small internal flues are used, they should be supported by suspension stay rods, two or three between the extremities. For the purpose of cleansing the boiler the front end should be recessed at the bottom, to allow the mud-hole door being large, directly under the flue. This is preferable to setting the boiler slightly inclined towards the front end. Steam chests, on the top of cylindrical boilers, are of great advantage, and the only cause of their not being universally adopted is the extra cost in construction, it being remembered that its construction requires time, labour, and material, the two former more in proportion than that for the boiler itself. We advocate the use of steam chests universally; it is essential for the production of dry and pure steam, and is a partial preventative of priming."

The importance of a rapid raising of steam has always been recognised by engineers, and very numerous have been the attempts to arrange boilers to attain it economically. Of these attempts the article now before us gives some very interesting and very suggestive notes.

"In the year 1828 a cast-iron boiler was constructed, egg-end in shape, thickness of the boiler about one inch, two feet in diameter, and about four feet in length. The idea was, that, instead of half filling the boiler with water, it should be made, first, red-hot, and, from jets of water forced in at the end centrally, the steam would be raised. It was, however, looked on as a fallacy, and as dangerous in the extreme. Old people shook their heads and predicted the sudden disappearance of both boiler and inventor after the first jet of water. Happily, science prevailed over ignorance, and steam was quickly and safely produced amidst the sneers and fears of the doubtful, who are now advocates of the scheme. The inventor was, as is too often the case, in possession of more brains than capital, and thus this really valuable invention was lost sight of for a season. At the present time we have cast-iron boilers on the same principle as that last referred to working with success, with the addition of a steam chamber. The adoption of spherical portions of cast-iron, connected together either by flanges, bolts and nuts, or long rods and nuts, dispensing with the flanges, has been used with much success. There is, however, this practical disadvantage: where connections are exposed to heated gases leakage is sure to ensue sooner or later, and more particularly with exposed or uneven surfaces. Consequently, in the multispherical boiler, the long bolt connections are preferable to those of flanges, and short bolts and nuts. It must not be overlooked, however, that, in the case of a leakage, disarrangement of the surrounding parts must ensue, to make good the defect. We now come to another feature of this class of boilers, viz., superheating. One portion of the number of spheres is devoted to the water, and the upper or remaining portion contains the steam, it being understood that both are entirely subject to the evaporating powers of the fuel used. Stop-cocks or valves are sometimes introduced, so that, in the case of fracture or leakage, the defective part can be rendered non-communicative with that in working order. Now, it will be seen by this description that the first example of cast-iron boilers bears no resemblance to the present one. We have had the opportunity, however, of inspecting a jet boiler at present at work with much success. A series of pipes forming a worm are laid in a brick fire-place of suitable construction and arrangement *of flues*, a jet of water is forced in at [illegible]nd, and steam is immediately generated and superheated ere it reaches the opposite extremity. A steam case or receiver admits the steam in a highly dry or purified state. The arrangement is more simple than the multispherical mode, on account of the lesser number of connections; at the same time the steam can be generated quicker. The dangers to be feared from the water being too low in the boiler, in this last example are entirely dispensed with, for when the engine ceases to require steam, the boiler has ceased to generate it. There is not the least doubt that this is the better mode of arrangement for boilers of the material and class we are now commenting on. It must be remembered, however, that in cast-iron boilers great care is required in construction. Cast-iron pipes, when broken, often expose the slipping of the core, so that one side is twice the thickness of that opposite ; now, for a boiler, whether the water is in a body or is supplied in jets, this defect would be of importance. The contraction and expansion of the metal would also be unequal, and thus greatly deteriorate the strength of the apparatus. We are aware that the moulders of the present day are fully capable of sustaining the cores strictly central, but that does not alter our belief that defects may sometimes occur and be discovered too late. It is also well known that the corrosion of cast-iron is not so rapid as that of the wrought material. neither are contraction and expansion so fully developed in the former as in the latter. These practical facts are, of course, in favour of cast-iron and its more general adoption, and we advocate its use for small boilers, but with careful construction and arrangement.

"With reference to the jet system one great fact must be noticed, viz., a small quantity of steam is generated at once and at the same time dispensed with into the receiver ; a self-acting valve might be introduced with great advantage to prevent the return of the steam into the generator. Having considered cast-iron boilers and their applications, we will return to those of wrought-iron. Small boilers, requiring no setting in brickwork, are usually vertical for stationary purposes. The flues are often corrugated to present an increase of heating surface in proportion to the space occupied ; in other cases tubes are introduced to gain the desideratum ; we have also known vertical flues in opposite directions (that is, up and down) to distribute the flame with advan tage. The small tubes within each other, or double tubular system, is correct in theory, but has often failed in practice. It has been proved that, to renew or cleanse the tubes, necessitates the entire disarrangement of the boiler. The internal surfaces of the larger tubes, and the external of the smaller, are almost inaccessible for scraping or cleansing, which operations are conducive to economy. This proves that simplicity of arrangement and accessibility for repair are the principal features of boilers, and exist in the Cornish boiler to which we have adverted. Makers of boilers for portable agricultural engines are undoubtedly improving their principles of construction; we find the consumption of fuel rapidly decreasing, but much yet remains to be done ere perfection is attained. There is undoubtedly a great waste of caloric in the direct tubular arrangement unless a great length of tube surface be resorted to, and the side return tubular arrangement greatly reduces the draught, but with the great disadvantage of two smoke boxes and an increase of boiler space. There is no reason why the fire grate and box should not be under the top row of tubes, the lower or bottom row being shorter than that of the top; the flame passing through the shorter tubes would ascend, pass through the top row, and thence through the chimney. This may seem complicated, but in practice it would not be found to be so; this arrangement has also the advantage of an increase of heating surface gained in a small space, with the same accessibility for repair as the ordinary arrangement."

7. *Small Boilers.*—A great help to the realization of economy in the working of boilers—and we may add of safety also—is having abundance of steam room, or rather general capacity. We have met with many instances in practice of the value of this plan of working steam boilers, and in a recent number of the "Scientific American," we find the following corroboration of it. "A most striking example of the utility of large boilers and the assertions here made was noticed by us some years ago in a factory. The proprietor of it had a small steam engine driven by a boiler large enough for two such engines. That boiler actually used less coal than one half its size for the same work; the fire once made in the morning burnt slowly through the day. Once *or twice firing* was all that was necessary, and the doors were con-

tinually ajar. The sluggish combustion was accelerated when new fuel was added by closing them for a few minutes. At night the fires were banked, remained so all night, and half an hour before work commenced they were ready for work. No kindlings were used from one week's end to the other, except to start the fire on Monday morning; no coal was burned to heat cold water every morning; no fuel was wasted, for it slowly roasted away to ashes, and the burning gases rising slowly through the flues and heating surfaces remained in contact with them and gave forth their utmost value.

"Half, if not more, of the miraculous economy claimed for cut-offs for engines with peculiar pistons; for valves with crooked openings instead of straight; for valves with three-fourth stems instead of seven-eighths, arises solely from their engines having surplus boiler power, wherein the coal is thoroughly burnt; where every ounce is reduced to ashes—not consolidated to cinder—and where the heat, instead of being discharged at the smokestack as soon as generated, is utilized in turning water into steam."

In a leading article in the "Engineer," under date July 21st, 1865—the same subject is also taken up and discussed. Of this we give the following abstract. The article commences by pointing out the difficulties attendant upon the introduction of motive powers requiring large-sized parts, and of the importance of compressing as much engine power into as small a size as possible; and thereafter proceeds to the consideration of the size of the boiler—drawing attention to the reasons—more especially in force in crowded cities—why boilers are crushed into the smallest of space, and their capacity of course proportionally reduced. "Turn where we will," says the writer, "indeed, in cities we find space at a premium, and boilers of the most abnormal designs taxed to twice their legitimate powers, habitually employed by those who know not which way to turn in order to obtain more power. If this be the case on land, matters are even worse at sea. A ship's boilers absorb the greater part of the most valuable space on board. Portable engines of all kinds, and possibly locomotives, would gain by a reduction in the dimensions of the generators from which they derive their power. No man has yet ventured to say how small a boiler can be made to suffice for the performance of a *given* duty, and it is worth while to question the wisdom of the policy which at present guides the great mass of boiler makers, or rather designers, on their way.

"The dimensions of a boiler are mainly determined by the amount of heating surface which it must possess, and by the arrangement of that surface. It is quite possible to produce a boiler every portion of the surface of which shall be directly or indirectly exposed to the action of the furnace; but it would be inconvenient, and, therefore, that portion of a boiler—the shell, in fact—not heating surface exerts a certain influence more or less subordinate. We shall not be far from the truth if we assume that the principal factor of size is the heating surface, and this, after all, determines bulk just as it is disposed. We may spread it out over acres of iron plate, or we may compress it into the shape of a few thousand tubes packed in a box. It is heating surface still, and we have nothing to prove that it is less efficient in the one form than in the other. Flue boilers make steam very well, so do tubular boilers; but flue boilers occupy much more space, and it is very far from being certain that they give any equivalent return for what may be a very expensive commodity.

"We find, again, that boilers possessing the same heating surface may present a vast disparity in efficiency, according to the temperature to which the surface is exposed. This temperature may depend either on the quality of the fuel, or on the manner in which it is burned, and certain conditions being present, it is certain that economy may be secured as well in the locomotive burning 100 lb. of coal per square foot of grate per hour, as in the Cornish boiler, burning but 4 lb. The efficiency of heating surface is measured by the difference between the temperatures at opposite sides of the plates. As these approximate, surface must be extended; as they depart from each other, it may be contracted; and thus it is that the mere size is not necessarily conducive to economy. In order, however, that a boiler working at high furnace temperatures may be at once effective and economical, it is indispensable that the circulation within should be very perfect. It is of no use to impart a high temperature to a plate unless water is present in quantity to take it up and convert it into power. There can be no doubt that this is the weak point of modern boiler engineering. Many of our locomotives are positively injured in the attempt to increase heating surface at the expense of circulation, and Mr. D. K. Clark deserves the thanks of the profession for the persistency with which he has pointed out that heating surface is one thing, evaporative efficiency quite another.

"In order to produce a small land boiler which shall supply the want which exists in all great manufacturing towns, it is indispensable that means be provided for burning a large quantity of coal per foot of grate—in other words, for producing a very high furnace temperature—and a good arrangement of surface for absorbing the heat developed. Flue surface is obviously out of the question—it takes up too much room. Tubes must be employed, and the manner of their disposition remains an open question. We are disposed to favour the "tubulous" or water-tube arrangement. Properly contrived boilers of this description suffer less from scale than any others, because they are blessed with a nearly perfect circulation. The manner of securing this circulation—of producing a good tubulous boiler, in fact—long presented a problem which has hardly yet been completely solved. Enough has been done, however, to prove that a boiler may be made with water within the tubes which shall be equally efficient, and yet much smaller than a boiler with the water without and the heated gases within. Years ago Dr. Alban made a very good boiler in which the water entered and the steam escaped from the tubes at the same end but at different levels, suitable plates being introduced to keep them distinct. More recently, Mr. Dickerson, of New York, has completed a set of water-tube boilers for the Idaho—a steamer the engines of which present much that is new, and a great deal that is good. In these boilers the prominent novelty lies in the steeply inclined position of the tubes—2 in. to the foot, or thereabouts—which debouch at each end into a water space, down which on the one side the water constantly descends, while the steam rises at the other. These generators have already been tested, we understand, with the utmost success, and theoretically speaking they are apparently as nearly perfect in design as boilers can be. Then we have the 'Field' boiler, so called from the inventor, in which the water tubes are vertical, and hang over the furnace. The descending current of water is *guided to the bottom* of the external tube by *another of common tin plate, of* smaller diameter, placed within it, and reaching nearly to the bottom. Such a device has been tried before now without success; but success in boiler engineering, as in most other things, depends on trifles. The original boilers made years and years ago, failed because the ascending current drove away the water which would fain have descended; the tubes boiled dry, and were burned out. Mr. Field appends a trumpet mouth to the inner tube, and thereby deflects the ascending current at the adjutage of the external tube, and the water is left free to descend from above and take the place of that evaporated below. This boiler should be good because the circulation is thorough; and we believe that, on the comparatively small scale on which it has as yet been tried, it has given much satisfaction. Day by day we find, indeed, that more attention is being given to the production of small boilers. It is not too much to say that the principal builders of steam fire engines in the metropolis have aided the cause materially; and when we find that Messrs. Shand and Mason have turned out a boiler weighing under one ton, which has developed not less than 32·25 indicated horse-power without expansion, we have good reason to hope that the day is not distant when dwellers in cities will find no difficulty in stowing away the motive power of their factories and workshops."

8. *On the Materials employed in the Construction of Boilers.*—In p. 73 of our first vol. (Facts and Figures for 1863) we gave some remarks on the use of "steel," and in par. 9, p. 38, of our second vol. (Facts and Figures for 1864), others on the use of "cast-iron." We now supplement these by an article from the "Scientific American," under date, August 12th, 1865. After describing the attempts made by Mr. Roper of Boston to reduce the weight and size of steam carriages, the article proceeds to describe the "boiler." "The shell is 30 inches long and 15 inches diameter. It is a vertical, tubular boiler with an internal fire-box, and the tubes are 10 inches long by $\frac{9}{16}$ths diameter. The shell, as well as the tubes, is made of steel, and it is in the employment of this material that Mr. Roper has been able to reduce the weight, and not only maintain but increase the evaporative efficiency of his boiler. The shell is $\frac{1}{30}$th of an inch thick, while the tubes are only $\frac{1}{40}$th. With this boiler steam has been raised *in eight or ten minutes*, and it is capable of bearing a pressure of

90 pounds per square inch with entire safety. It supplies all the steam necessary for the two cylinders, and propels the carriage eight or nine miles an hour without any difficulty.

"In this machine we have one of the most novel steam boilers ever made. And it is a matter for earnest consideration whether, in the employment of cast steel for steam boilers, we may not only greatly increase the strength and reduce the weight, but also add to the economy of the apparatus, by facilitating the transmission of heat. To use a homely illustration, a thin tea kettle boils more quickly than a thick one; and, for the same reason, steam boilers with unnecessary heavy flues, flue sheets, fire-box walls and furnace crowns, transmit less heat than lighter ones. The only danger to be apprehended in departing from the established time-honoured rules and precedents in this case, is in weakening the structure. An example of what a thin iron flue is capable of sustaining, was shown in Lee and Larned's steam fire-engine *Niagara*. This steamer had a large vertical boiler, the tubes in which were but $\frac{1}{30}$th of an inch in thickness and 1½ inch diameter, by some four feet long. We have repeatedly seen 240 pounds to the square inch on this boiler, or others with tubes no larger or thicker. Some of the tubes were occasionally collapsed so flat, however, that neither steam nor water could pass through them. These were drawn iron tubes; but if steel had been employed they would not have failed, because the latter metal has a higher tensile strength.

"Another lesson on the value of good workmanship is given by Roper's boiler. To bear the pressure required of them, the tubes must necessarily be small in diameter. They were, therefore, all drilled and turned, and were thus homogeneous throughout. Such a method of making a steam boiler is, of course, expensive; but if the evaporative efficiency is increased thereby, as it is, it is only a question of first cost, for the money returns in the future by the fuel saved.

"The rapidity with which heat is transferred from one substance to another is directly in proportion to the difference of temperature between them.

"The conducting power of steel is lower than that of iron; the former being, according to experiment made by Weideman and Franz, 224; while steel is but 218. But this difference so small as to be of no moment, and is wholly nullified when the tensional strength of the two metals is considered; for, by taking advantage of the superior virtue of steel we can make a structure much lighter of it, for a given strength. Moreover, in a cast-steel boiler, the rapidity with which heat would be transmitted through the thin walls would be less likely to burn the exposed parts—the tube, sheet and fire box crown—than in the comparatively slow action of thick iron plates.

"Very many persons confound strength with weight, and suppose that, because a number of pounds of material are added to a certain part, a corresponding increase of strength is obtained. Nowhere do we find this more prominently illustrated than in steam boilers; too often the essential points of safety are neglected, while those which bear no strain are heavy in the extreme.

"It is, therefore, with a view to promote the efficiency of steam apparatus and economy in its use that we suggest further experiments in this direction. Cast-steel of fine texture, well riveted and annealed very low, would seem, from the experiment of Roper, capable of sustaining great pressure. We doubt if a boiler 30×15 inches was ever made which furnished so much steam, or was capable of evaporating so much water in proportion to its size, as this one. If, by a corresponding increase in the thickness of the plates and the external dimensions, boilers can be built of proportionate strength, a great economy of space would result in sea-going ships."

9. *The form of Marine Boilers.*—In an article by Mr. N. P. Burgh, in the "Mechanics' Magazine,"—under date March 3d, 1865,—much valuable information is given on the above subject; of this we give the following abstract. After pointing out that, although much has been done of late years to improve marine boilers, still there is ample room for farther improvements being introduced; the writer proceeds to classify boilers of this class into two sub-classes, "high,"—this class being used in commercial steam, and "low,"—this being used in the war steam vessels. The shape of the boiler is much influenced by that of the hull, but generally the form used is the "square-shaped shell," the cylindrical being used but rarely, except for gun boats or barges. *As regards strength,* the cylindrical is superior to the square shell.

After sundry remarks upon the heating surfaces of marine boilers the writer proceeds to describe the "peculiar forms" as at present used. "The high boiler, as well known, has the tubes directly over each fire-box; the combustion chamber being in some cases in one compartment and in others separate for each set of tubes, which is undoubtedly the better plan. When the combustion chamber extends the entire length of the tube space there is a loss of water spaces and heating surfaces, and at the same time a difficulty in constructing the connection of the fire-box with the chamber. Some makers have lately preferred the separate arrangement on account of its being the better for combustion and repair; but in the case of renewal of the tubes the chamber, when in one compartment, may be said to admit of more room for the operations of the workman. We have stated that the portion of the boiler below the fire-grate is of little or no use for evaporating purposes; such being the case we often see boilers with the water spaces between the fire-boxes at the sides and that at the bottom dispensed with. There may be objections to this arrangement on the ground that the space, when exending over the entire bottom of the boiler, acts as a receptacle for the sediment, whereas, when the spaces are at the sides only, the sediment collecting thereat may be the means of destroying the fire-boxes by burning, corrosion, &c. When distilled water is used for the feed there need be no apprehension about the collection of the sediment; but where river water is used in its natural state, a constant collection accumulates, requiring periodically to be blown out. As regards the fire-boxes of the boilers now in question, in many cases they are made too low directly over the fuel. Combustion requires space to commence its operations. As before stated, all gases have a tendency to ascend; consequently, this should be one of the natural laws the designer of boilers should study as much as the space allowed will admit."

After referring to the question of smoke consumption in marine boiler furnaces, the writer concludes with the following upon low boilers. "Cylindrical boilers," he says, "are not universal. Their arrangement is as follows: the fire-box being in the front part of the boiler, and the tubes arranged beyond, similar to the present arrangement for locomotives, it is needless almost to state that there is a waste of caloric in this arrangement, unless boilers of an increased length are used. The next arrangement of cylindrical boilers that has come under our notice is that in which the fire-box and the flue are extended the entire length of the boiler, minus the combustion chamber; the tubes are arranged over and partially around the passage alluded to, the flame and heated gases returning back to the smoke-box, directly over the fire end of the flue, or rather the front end of the boiler. Such an arrangement required an increase of area in the boiler transversely, to that of the former example, in order to preserve sufficient steam space, which, be it remembered, should be attended to in all cases."

9*a*. *Marine Low Boilers—Long and Short Tubes.*—In the "Mechanics' Magazine," under date of April 14th, 1865, in an article on the above subject, there are some very suggestive remarks on the importance of "maintaining the position both of engines and boilers below water line." In another article (see preceding par. in the present section), the writer advocated the adoption of high boilers in vessels in preference to the low class; but of course in vessels only of sufficient tonnage to admit of the boiler being below water line. In war vessels it is clearly of the utmost importance to have the boiler out of the reach of shot. "Low" boilers for vessels, as now used, are divided into classes, those with "direct" and those with return tubes. In Fig. 3, a form of low boiler is illustrated; before describing this the writer discusses the relative advantages of long and short tubes. "It has been practically demonstrated that, when heated gases proceed with great velocity through short tubes, the temperature of the surface is much below that in those of greater length. The cause for this is, of course, due to the time the flame or heated gas remains in the tube. Take, for example, the heating department of a sugar factory, where, by a series of pipes or a worm in the stove, a great temperature can be maintained with economy. Also for refrigerators the long piping or tubing is superior to the shorter arrangement. Surface condensers afford practical evidence that a long tube is preferable to a short one. Now, as regards the diameter of the boiler tubes, we advocate 2½ in. as a minimum and 3 in. as a maximum. When reference was made to worms it was not meant that that shape would be applicable for boilers. At present we allude to boiler tubing in respect of its action, not of its construction. In this arrangement (Fig. 3), it will be understood that the fire-boxes are at opposite positions, centrally, of the transverse section of the boiler. The flame and

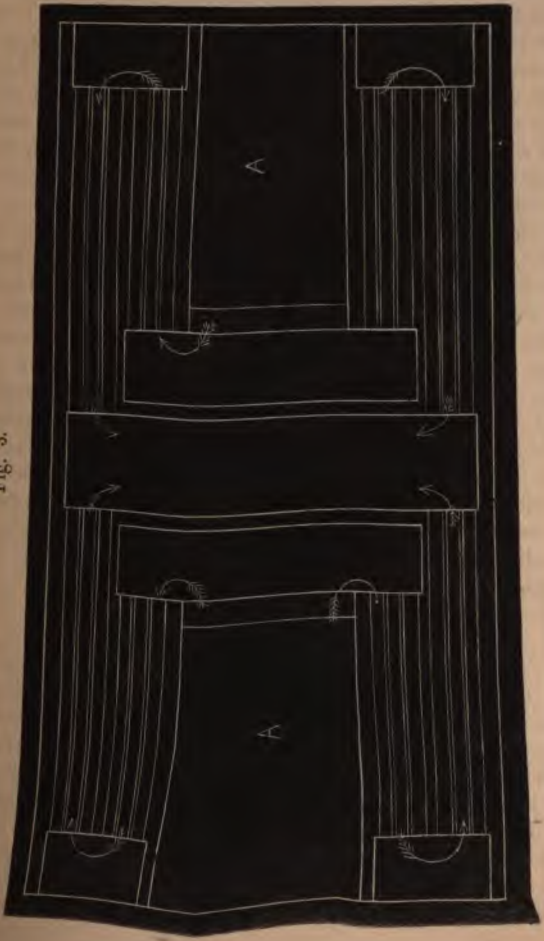


Fig. 3.

heated gases pass from the combustion chamber through the tubes arranged on each side of the fire-boxes, the return or exit being through the tubes at the sides of the boiler, and thence to the smoke-box situated centrally of the same. By this arrangement simplicity of construction and repair is attained, whilst the tubular surface is doubled, with equal action and space. Another important gain is, that the flame has to pass through four sets of tubes ere it reaches the smoke-box; the flame also having to split in the combustion chamber, is properly equalized in power and draught. The distribution of the heating surfaces and water spaces within the shell of the marine boiler (particularly the low) is a matter of the greatest importance. We know of boilers where the crown of the fire-box is much above the upper row of tubes; such an arrangement imparts unequal evaporation; hence the partial cause of priming, &c.; there is also great danger to the vital portion of the boiler in the case of the water being too low. It is not unusual to see the gauge glass full one minute and the next empty. The reasons for distributed and equal heating surfaces are, therefore, apparent. As we have given a plan only of the boilers, it will be necessary to state that, in the case of fig. 3, the repair or renewal of the tubes relating to the smoke-box is effected by a door on its top, near to or at the top of the boiler, care being taken to allow sufficient space for the manipulation of the tools required. With reference to the arrangement of the stays, the advantages in the examples given are equal, all the parts assisting each other in relation to the pressure imposed."

SECTION SECOND.

10. *The Appliances of Boilers and their Practical Management.*—The reader will find in our vols. for 1863 and 1864, many valuable remarks in connection with this important department of boiler engineering. An able article under the suggestive title of "Boiler Guardians," in the "Mechanics' Magazine," under date, April 14th, 1865, goes pretty fully into the points connected with *safety valves*, and of which we here give an abstract. After pointing out that although great attention has been paid by inventors to this class of boiler appliances, and the

forms of apparatus introduced have many of them presented much that was valuable; nevertheless, with all that ingenuity has devised or "can devise, it has not yet succeeded in producing such articles as satisfy all the conditions required of them." But perfect as such appliances may be or are, it is obvious enough, as pointed out by the writer of the article, that much depends upon their management by those attendant upon the working of the boiler. Against recklessness and mismanagement there is, and can be really, no mechanical preventative. We regret that space does not admit of our reproducing the excellent remarks of the writer on this point, and can therefore only refer the reader to the article itself, and pass on to the more immediate department of our remarks. The causes that bring about boiler explosions have been by a pretty widely extended experience shown to be two chiefly; these are, "first, a pressure of steam exceeding that which the boiler is calculated to withstand, and, next, a deficiency of water. The former is due to the safety-valve being inoperative, insufficient, or improperly tampered with; the latter either to neglect and inattention on the part of the engineman, or to the usual fittings being out of working order. *Deficiency of water* is the immediate cause of a great number of steam boiler explosions, and even where boilers do not explode they are often seriously injured from this cause, and their term of usefulness materially shortened. The primary cause of deficiency of water is evaporation, which leaves the naked plate to the action of the fire, thus weakening the boiler, the heated part being unable to stand the ordinary pressure. Deficiency of water has also occurred from many other causes, such as the pumps getting out of order, or from dirt finding its way into the valves and pipes, the engineman, too, being deceived by the sticking of the float wire, from wear in the packing, and, very frequently, from erroneous indications of the glass gauge caused by the stoppage of the thoroughfare to the boiler or the taps being tampered with. In cases where gauge taps only have been in use, the engineman has been deceived, when on opening the tap the water has primed and come out even when deficient in its height in the boiler. Now to remedy all these defects and to guard against mishap is the province of the fittings under consideration, but where do they act up to their requirements? As a rule, they cannot cope with all the exigencies referred to, and were they to do so there is no guarantee for their efficiency if ignorance or wilfulness step in and upset them. It is true another guardian has long been added in the shape of a *fusible plug*, which is supposed to be infallible, inasmuch as it is beyond the reach of tampering, and is so constructed and placed that its proper action appears inevitable. But the many explosions which have occurred where the fusible plug is adopted are a proof of its inefficiency. Some boilers are fitted with a gauge of novel description, which admits of the interior of the boiler being seen while in actual work. This is accomplished by a glass eye-piece, the boiler being illuminated by means of a light shed through a lens which lights up the whole interior of the boiler, and shows the surface of the water in ebullition. But this, and all other contrivances, however ingenious, are of no use against carelessness or wilful neglect. As far as the apparatus is concerned the object is to have such as possess neither spindles, guides, rubbing surfaces, nor parts liable to stick, and which cannot fail to indicate truly, according to its functions, either the state of the steam pressure or of the water level when the one or the other is in a condition from which damage may be apprehended, and which at the same time shall be so constructed and placed as to render abortive any attempts to tamper with them. If these conditions can be complied with in one instrument which is applicable both to steam and water purposes, an evident advantage must accrue. Hopkinson's compound safety-valve appears to answer these conditions. It comprises two distinct valves, a large 5½ in. diameter valve with flat face and a spherical or ball-faced valve 3 in. diameter; the smaller or ball valve seating upon the centre of the larger one. The larger valve is weighted by means of a lever and ball, as in the common safety-valve; there is an iron bridge or cover casting which fits to it, and forms the centre for the centre-pin to give pressure upon the valve enclosed. Resting upon the centre of the large valve is the ball valve, which is weighted by a dead weight inside the boiler, the dead weight being composed of cast-iron plates. When the steam exceeds the pressure this ball valve is weighted to, it escapes through the openings in the bridge casting into the dome or shell, and out into the atmosphere. As soon as the ball valve lifts from its seat the large one lifts from its seat, and thus a double discharge is given to the excessive steam. The feature here presented is of importance, inasmuch as an opening or discharging area, equal to ordinary safety-valve of 8½ in. diameter, is obtained. The valve cannot be weighted beyond its working pressure whilst the boiler is at work; should an attempt be made to weight the lever it would be useless, so long as the ball valve is there; and even should the ball valve be weighted intentionally whilst the boiler is standing for cleaning, &c., it may instantly be detected by placing the ball on the lever in its ordinary working place; as, by getting up steam, such tamperings and their extent will be discovered by the marks on the lever; when the boiler is at work it defies any tamperings. The steam can be blown off as with any other valve. Its next feature is an improved arrangement for noting the deficiency of water, for which purpose a lever is suspended in the boiler; the rod which bears the weight for the ball valve passes through a large hole in the centre of this lever. On this rod is fixed a disc which is arranged so as to allow two lugs on the lever to come in contact with it. One end of the lever or beam suspended in the boiler bears a large float, the opposite end having a balance weight to counteract the buoyancy of the float when immersed in the water, and to keep the tip of the lever up against the under side of the top of the boiler; the float is immersed in the water to such a depth as is called low water mark. When the water begins to leave the float its weight acts upon the end of the lever, which turns upon a centre; the lugs are brought into contact with the disc on the rod, and the valve is raised from its seat. Should the water still get lower the valve continues to rise, and will do so until the supply brings it again to its proper height. Should the warning be disregarded the steam will be all discharged from the boiler, and explosion rendered impossible.

"This valve was designed to prevent the careless, the ignorant, or the wanton, from causing either injury to the boiler, or boiler explosions, and from its extensive use may be inferred its efficiency. But that it can be, and sometimes is, tampered with, proves the difficulty of dealing with the class of men just referred to. A case in point came under the notice of Mr. Longridge, who reports the examination of a boiler in which it was found by calculation that a small lever safety valve, with which it was provided, was loaded to 106 lbs. per square inch, although, according to the gauge, steam blew off freely at 62½ lbs. pressure. The owner disputed the accuracy of the calculations, and apparently with some reason, inasmuch as steam blew off at the same time from one of Hopkinson's valves, with which the boiler was also provided, the pressure graduated on the lever being only 60 lbs. per square inch. On subsequent examination, however, it was discovered that this valve was overloaded by extra weights attached to the lever inside the boiler, and that the pressure gauge indicated 43½ lbs. less than the actual pressure. The extra weights had, of course, been attached unknown to the owner, and not improbably under the impression that the actual load on the valve did not exceed that indicated by the gauge. This is only one of a number of similar incidents which form a striking comment on the pertinacity with which men will stick to bad habits, and show that engineering vices are as ineradicable as any others, and that if they cannot be indulged in openly they will be on the sly.

"Another boiler guardian—and one to which this name has been given—was exhibited by Featherstonhaugh and Wise, and received honourable mention, in the Exhibition, 1862. The contrivance is very simple, and its objects are—to regulate the action of the feed pump so that the water shall be maintained at a nearly uniform level; to show the height of water in the boiler; and, in case the water level falls below a certain line, to call attention to the fact by sounding an alarm. The apparatus consists of a copper float attached to a lever within the boiler, to which is connected a small gun-metal slide (working at the back of a dial plate outside the boiler), which rises and falls with the float, and, when the water level is slightly in excess of the mean height, opens a port whereby air or steam is admitted to the suction pipe or working barrel of the feed pump, thereby suspending its action until the falling of the float shuts off the air or steam and causes a vacuum to be again formed in the pump. But if, notwithstanding the shutting-off of the air or steam, the pump from any cause fails to act, the continued falling of the float and slide opens a port and admits steam to a whistle, which *at once* makes known the fact. The index needle is worked by means of a pin projecting forward from the face of the slide. The apparatus requires that only one small round hole should be made in the boiler, and it can be affixed or removed in a few minutes; the feed pump connection consists simply of a small copper tube." We follow up these remarks by a few notes upon boiler appliances recently introduced.

11. *M. Carre's dioptrical water-gauge.*—"The distinguished labours," says a writer in the "Practical Mechanics' Journal," "of M. Carre, resulting in the successful completion of his ice producer, which occupied so important a position in the French department of the International Exhibition, 1862, appear by no means concluded, for, with the view of ascertaining more perfectly the level of the liquid employed in that apparatus, he has devised a new form of gauge, the application of which is not, however, confined to the ice producer especially. Its peculiar features especially adapt it as a substitute for the ordinary water-gauge of steam-boilers, the great disadvanges and anomaly of action belonging to which have been previously pointed out by the present writer in the "Practical Mechanics' Journal."

"The gauge now under notice has been patented in this country, and may be obtained from F. D. F. Leblanc, 102 Fleet Street, London. Its general arrangement may be briefly mentioned thus:—In one modification the gauge-glass is enveloped in a metallic casing, in which a series of holes are perforated, the axis of any two opposite holes being exactly coincident. Although the use of a metallic casing as a protection for the glass tube against fracture from accidental blows is by no means new—the writer having employed it many years since for this purpose—still, from the peculiar manner in which M. Carre has adapted it, it serves another very important purpose—dependent in combination with the tube, for the certainty of making true observations, upon a correct application of some of the principles and laws of optical science.

"When the perforated casing and tube are combined, those portions of the tube visible through the perforations become a series of lenses, which when the tube is empty, produce the effect of a cylindrical lens, but, when filled with water. its power is that of a bi-convex spherical lens.

"Upon looking through the orifices, both above and below the water level, the axially coincident holes present two different appearances—in the former case, the opposite holes appear elliptical in form, the main axis being situated vertically—whilst, in the latter, they appear in their true shape, circular. There are other modifications of this unique invention, but for general purposes, the practical adaptability of that one to which reference is made, appears to assign to it the most deserving consideration, and on that account these remarks are confined to it alone. The objections to the ordinary glass tube water-gauge might almost assume the name of legion, the greatest of which is the impossibility of determining with certainty the true level of the water in the boiler. A boiler may be greatly too full, still the gauge has been known, in endless instances, to appear quite empty. On the other hand, the gauge may indicate a full boiler, when in reality the steam is low.

"It is perfectly true that these objections are not altogether overcome by the dioptrical gauge, for those constructive features of ordinary gauges, causing the anomalous indication of water level—as pointed out in the previous article on this subject—are in it not removed; and the writer ventures to believe that the period is not very far distant when an ordinary plate of glass of sufficient thickness to resist any casualty of over-pressure will be fixed into the boiler proper, with suitable shutting-off apparatus, by the adoption of which true indications of water level must result, and any anomaly arising from the possibility of fracture would be entirely avoided."

Fig. 4.

In Fig. 4, we give a diagram of one form of this water-gauge, in which A is the hole over the empty part; B, hole over the meniscus; C, hole over the full part. "A rather thick-sided glass tube can be looked upon when empty, as a *cylindrical lens*, which is the double equivalent of a spherical lens, scientifically termed in French *menisque concave* or *periscopique concave;* when filled with water, however, the glass tube gets to be the equivalent of a bi-convex spherical lens. From this it follows that the holes in the casing appear, in the part containing no water, under the form of an ellipse, the major axis of which is parallel to the axis of the tube, while the portions full of water show a transverse ellipse."

12. *Location of Steam Gauges and Indicators.*—"A correspondent of the 'Scientific American' states that he has two steam boilers connected by a pipe, which is furnished with a stop valve for closing the communication between the boilers. He recently had the valve closed, and found that the pressure in one boiler was 50 lb. to the square inch, and in the other 20 lb. On opening the valve the pressure immediately rose to 65 lb. It would be interesting to have further particulars in regard to this experiment, but with our present light we are inclined to attribute the surprising result to the location of the gauge in such a position that it was acted upon by the current of steam in its passage from the high pressure boiler to the lower.

"The action of currents of steam, though familiar to engineers in other situations, seems to have been strangely overlooked in its effect upon gauges and indicators. Clark, in his most able work on the locomotive, states that repeated observations showed the pressure to be greater in the steam-chest than in the boiler; and he remarks that, from the carefulness with which the observation was made, and the perfection of the instruments, it is as difficult to doubt the statement as it is to believe it. There may be difficulty in doubting the statement, but to believe it is simply impossible. Steam will not flow from a vessel of lower pressure into a vessel of higher pressure. There must have been some error in the observation, and a very probable cause of this was the location of the gauge in such position that it received the impact of the swiftly moving current of steam which rushes from the boiler into the steam-chest. Currents of steam may operate not only to raise the mercury in a gauge, but also to lower it so as to indicate no pressure whatever, even in engines working steam at a pressure of 30 lb. or 40 lb. to the inch. This effect is produced by inserting the gauge pipe at right angles to the current of steam, when the steam is drawn out of the pipe by the friction of the passing current, and we may even have the indication of a partial vacuum."

13. *The Injector.*—A great deal has been written and said upon the subject of the injector, its operation and utility; and

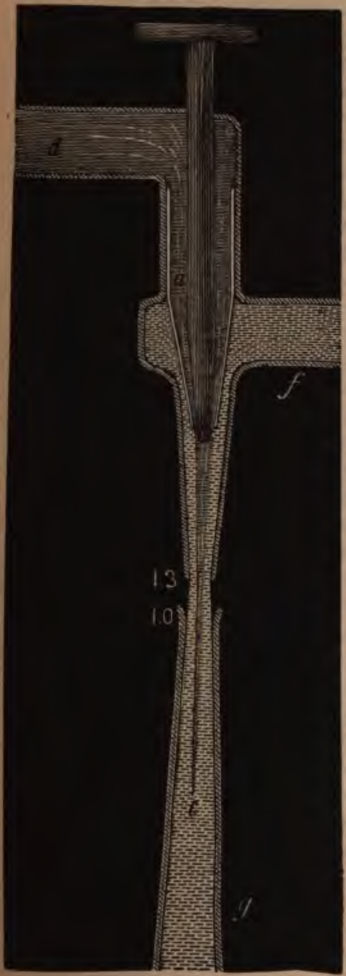
very diverse indeed have been the opinions upon these. Mr. Robinson, who, in the works of the makers of the injector in this country, has had a large experience in connection with its practical working in almost all conceivable forms of use, recently read a paper before the British Association, from which we take the following extract and illustrations:—"Although much has been written and considerable discussion has arisen as to the mode of operation of Mr. Giffard's injector, there still seems to exist sufficient difference of opinion on this point to warrant the introduction into this paper of some words on the theoretical action of the instrument.

"This action may be stated generally thus:—Steam is taken from the steam space of any boiler; by means of the injector the water supply is brought into contact with the steam current, and the result, in the shape of hot water, is passed into the water space of the boiler.

"How, then, having equal pressure in all parts of a boiler, does a fluid not only pass in the shape of a current from one part to the other, but at the same time carry with it another fluid exposed to atmospheric pressure only? A description of the apparatus will help to the apprehension of the phenomenon, and a drawing, Fig. 5, on a large scale, is exhibited for this purpose.

"The chief organs of the instrument are *a*, the steam cone; *b*, the combining cone; *c* the receiving cone. Through *a* the steam flows from the pipe *d* in connection with the boiler, the quantity being adjusted by the regulating spindle. To the combining cone *b* the water is admitted by the supply pipe *f*, where it joins the steam arriving through the cone *a*, the proportion of water being regulated by the rise and fall of the cone *a* within the cone *b*. The mouth of the cone *c* is placed at a fixed interval from the smallest end of the combining cone *b*, from which it receives the steam resulting from the contact of the steam and water in *b*, and conveys it at a gradually diminishing velocity into the boiler through the pipe *g*. The unit of area is that of the smallest diameter of the receiving cone *c*, which being 1, the diameter of *b* is 1·3, and that of *a* 1·4 to 1·5, according to the steam pressure employed, the corresponding areas being—of *c*, ·7854; of *b*, 1·327; *a*, 1·539 to 1·767. It will thus be seen that the area for the admission of steam is double that which receives the condensed steam and water.

Fig. 5.



"Keeping this in mind, the next consideration is the velocity of the currents concentrated in the apparatus. Assume a steam pressure of 60 lb. in the boiler, the velocity of the steam current into cone *a* would be 1,712 ft. per second, that of the water into cone *b* *nil*, and that of the hot water from the boiler, if allowed to escape through the cone *c* into the atmosphere, 78 ft. per second.

"It is evident, therefore, that to gain admission to the boiler, the steam flowing into cone *c* must do so at a greater velocity than the outflowing current from the boiler. The two elements for giving this superior velocity are, first, the initial velocity of the steam issuing from cone *a*, diminished by its contact with and condensation by the supply water in cone *b*, but aided by the superior area of the lower part of the steam cone *a*, and its concentration by the arrangement of the apparatus on to the inferior area of the smallest section of cone *c*. The mode of setting the apparatus to work is as follows:—

"1. Turn the handle *g*, Fig. 6, (see p. 48) to the position suited to the steam pressure in the boiler, thus adjusting the annular space between cones *a* and *b*.

"2. Turn slightly the wheel *d*, which will pass a small quantity of steam through the apparatus until water is seen to issue from the overflow pipe *l*.

"As soon as this happens, continue to turn upwards the wheel *d* until the overflow ceases, and thus give full liberty to the steam to act upon the water, and drive it into the boiler through the cone *c*.

"If, however, after having turned the wheel *d* to the extent of its range, the overflow still continues, it should be stopped by reducing the quantity of water by the handle *g*. The injector is working properly when there is no dropping from the overflow pipe, and no more steam is admitted than is absolutely necessary to prevent that dropping.

"The quantity of water delivered into the boiler may be reduced by turning down the wheel *d*, and then following with the handle *g*, until the overflow stops again.

"The following experiments, made with an injector of 8 in. in diameter of receiving cone, will illustrate the capabilities of the apparatus:—It will be easily understood that the acquisition of an apparatus capable of supplying water to steam boilers without motion of any of its parts, and independently of any engine connected with it, is a matter of great importance to the users of steam power generally, and has proved almost essential to some particular arrangements of boilers and engines. For locomotives the advantage has been very considerable, inasmuch as it is most important that the machinery of engines running at such high velocities should be freed from the apparatus and repairs necessary when their boilers are fed by pumps worked by the engine. The advantage also is obtained of feeding the boiler while the locomotive is at rest either in the station or during its detention in a siding waiting for the line to be cleared. For this purpose, 5,230 have been manufactured in this country. For stationary boilers the injector has been found convenient, because of the saving of the pipes and other communication from the boiler to the engine-room, the suppression of the pumps and the parts of the engine necessary to work them, and the advantage of being able to fill up the boilers during meal hours and at other times when the engine is stopped. For this purpose 3,816 have been made in this country.

"For marine boilers the apparatus is most convenient, since it answers generally the purpose both of the main engine pumps and of the donkey pump, and brings the control of the feeding apparatus within reach of the stokers without reference to the engine-room, and without the noise and complication of the donkey pump. In a similar form, and also in the ordinary injector arrangement, the principle has been applied for raising water from mines and wells, the inducement being the cheapness and simplicity of the apparatus when probably its use would need to be only temporary; and in other cases the small space and easy manipulation required have been thought a sufficient inducement to apply it where fuel has been cheap, and the loss by waste of heat in the water elevated of little consideration. . . .

"It was afterwards found that the long diverging tube or cone was not necessary to the success of the apparatus, and the length of this organ was therefore reduced to that shown in Fig. 6, and still retained. An inconvenience arose, especially in the case of boilers working a very high pressure, from the rapid deterioration of the packing H above the steam cone A. This was sought to be obviated in an arrangement in which the steam cone is fixed and the combining and receiving cones are moved with each other, being attached by a cylinder."

On the same subject a paper was read before the Institution of Civil Engineers, by Mr. T. England, from which we take the following extract bearing upon a method of working the injector on the Western Railway of France, introduced by M. Turck. "Steam was maintained to the indicated pressure of 9½ atmospheres; going down inclines, the boiler was filled to the maximum water level, and it was supplied during stoppages at stations, care being taken to arrive with low water. In those stations where the engine had to remain for some hours before starting, the steam was at 2, or at most 3 atmospheres; and, as soon as the engine was shunted, the injectors were set to work to fill the boiler, using up the steam—which would, with pumps and without a donkey engine, be wasted—to 0. There were engine-men who, when the steam was blown off, which seldom happened, were enabled to heat the water in the tender, and who, by feeding on the inclines and at stations, saved, as compared with the same boilers fed with pumps, but without a donkey engine, a kilogramme and a half *of fuel per kilometre.*

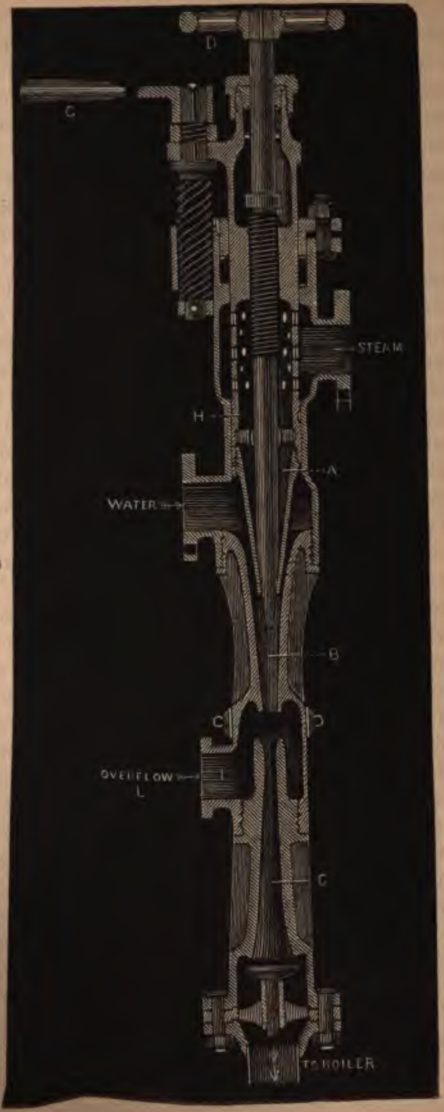


Fig. 6.

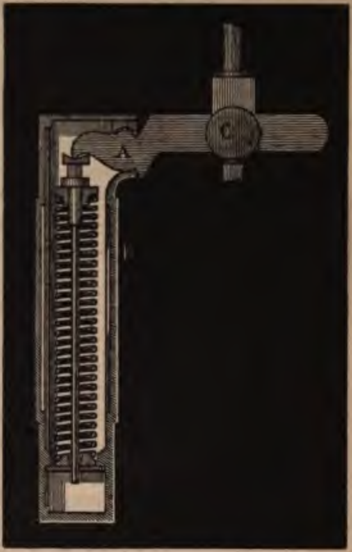
"The test of the injector appeared to be, its comparison with an apparatus, such as Mr. Beattie's, which, abstracting its first cost and that of maintenance, by utilising the heat of the exhausted steam, and by delivering the water at the boiling point, was asserted to effect a saving of fuel to the extent of 13½ per cent., as compared with any process, other than that of the injector, delivering feed-water at the temperature of 50 degs. The apparatus was described, but it was contended that this method did not effect a saving of more than 9 per cent. To set against this there was the excess of first cost and of maintenance, the greater liability to accidents, and the increase of back pressure. These were deemed to be so considerable that most railway companies, both at home and abroad, now adopted the injector for all new engines.

"It was observed that the application of this instrument as an elevator opened a wide field for its employment; and in conclusion a list was given of all that had been published in France and in this country relative to the injector, which, with the exception of the information furnished by M. Turck, had formed the data on which the paper had been prepared."

14. *Camerer's Safety-valve Balance.*—The following description and illustration of this effective appliance we take from the "Scientific American." "This simple and durably-constructed balance, illustrated in Fig. 7, was originally intended for locomotive engines, but can also, with great advantage, be used on marine engines, or any place where a dead weight is objectionable.

"It is well known that a dead weight on a safety-valve lever is the most desirable and safest, wherever it can be applied; but on locomotive boilers, which rest on springs, it cannot be used, as its action on the valve would be influenced by the vibrations continually occurring. On marine boilers, where weights are still in use, the rolling of the ship occasionally makes it necessary to lash the levers down until the weather moderates, thereby destroying the only virtue of the valve. Spring balances, as generally made, are more or less objectionable, on account of the springs becoming stiffer as the valve rises. Various plans have been adopted to overcome the defect by regulating the strength of the springs, thereby depending on the vigilance of the engineer to prevent the pressure from getting too great; whereas,

Fig. 7.



the balance here illustrated, requires no attention whate
in use, as an increase over the allotted pressure cannot ta

"The arms, A A, can rise as much as the safety va
require, without additional pressure, which makes this
equal in efficiency to a dead weight. An example will
disadvantages of spring balances now in use more appare
instance, if a safety-valve lever is held down by a sp
other end of which is fastened to the boiler or some ot
point, the lever cannot rise without increase of power
above the pressure it was calculated for; and if the pr
for length of lever are as 1 to 10, then the valve cannot
one-eighth of an inch without raising the end of the
times one eighth, or 1¼ inch—which distance is, on
dinary spring balance, equal to 28 lbs.; and ten times 2
lbs., on the valve. Now, if we have a valve of 2½ i
ameter, or 4·9 square inches area, the additional pressu
be 57 lbs. per square inch to lift said valve only one-

an inch off its seat. Under such circumstances it ceases to be reliable, and requires watching and regulating to avoid over-pressure or accident.

"The advantages of this improved balance are in the peculiar lever arrangement, by which the above enumerated faults are avoided. The arms of the levers, A, inside of the casting, B (see Fig. 7), from the fulcrum to the springs, are at an angle with the outside arms; and an upward movement of these outside arms is accompanied by a corresponding downward, and also an inward movement, of the inside arms resting on the springs; therefore, the more the springs are compressed the shorter the effective length of the inside arms will be, thereby increasing the power of the outside arms in the same proportion as the springs get stiffer from compression, thus enabling them to rise the required distance without increase of power. The rod C is fastened by a set screw to any distance from the fulcrum, according to the pressure required. Close behind this rod a small pin can be put through the arm, to prevent the engineer from increasing the pressure beyond what the boiler was intended to carry; but as much of the arms as is not in the way of anything, may be allowed to protrude, for the purpose of decreasing the pressure, should any accident to the boiler make it desirable to do so. To keep up a uniform pressure of steam is considered far less injurious to a boiler than the sudden changes, produced by slacking or screwing down safety-valve levers. Such changes will not take place where the improved balance is used.

"The springs are made of hard brass wire, expressly drawn for these balances, and are not liable to corrosion, as is the case with steel springs; and, being compressed when working, are far less liable to break or to lose their elasticity.

"These balances have been in use for more than a year on several of our leading railroads, where they give entire satisfaction."

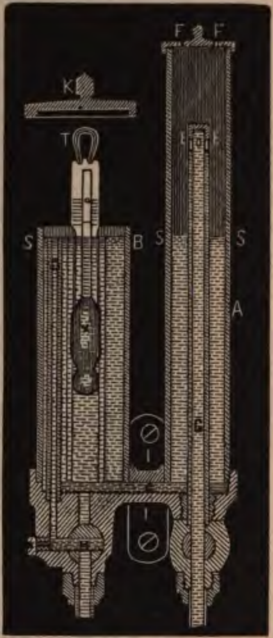
15. *Salinometers.*—"Sea water," says a writer in the "English Mechanic," "contains a certain quantity of salt, in the proportion of 1 lb. of salt to 32 lbs. or 33 lbs. of water, and as all the water evaporated is fresh, all the salt is left in the boiler, which would cause its destruction if not removed. This is done by blowing out, at intervals, a portion of the partly-saturated water from the

boiler. Scale is not formed in a boiler until the water has reached a certain degree of saltness, and if it is kept below that point, the boiler will be kept clean; but if allowed to get above, incrustation takes place, and continues as long as it is above. Hence the necessity of keeping the water in the boiler at a proper and uniform degree of saltness, resulting in a saving of fuel as well as a saving of the boiler.

"In most steamers a much greater quantity of hot water is blown off than is necessary, and even then the boilers are not kept clean, because it is not always blown at the proper time. Large quantities of hot water are often blown off when not necessary; and, at other times, when water ought to be blown off it is not done, except there be means for ascertaining when it is necessary, or how much is required to be blown off. The means which are at present in many cases employed for this purpose are altogether insufficient and unreliable, as they do not—as they ought—enable the engineer in charge at once to ascertain the density of the water. In order to do this he must, firstly, draw water from the boiler into a tin or copper can, next insert therein a hydrometer and then a thermometer. In heavy weather this is no easy task. Often the hydrometer alone is used, and, as it is graduated for a certain temperature, should the temperature of the water not correspond therewith, a guess must be made, and, as might be expected from this haphazard way of working, either good water is wasted, or the boiler is burned. In some steamers a potato or a piece of coal is said to supply the place of the hydrometer. Thus, that which in the interest of the steam-ship owner should be the first point of attention both for saving of fuel and prevention of injury to the boiler, seems to be thought by some a matter of no importance. It will be obvious, from what we have said above, that any arrangement of instrument devised for indicating the density of water in marine steam boilers should be so connected with the boiler, that a constant flow, or current, may be maintained through it, and the indication of both thermometer and hydrometer at any time, and at a glance, 'read off,' also that some means should be provided for regulating the supply, so as to maintain the water in the salinometer at a given temperature—that for which the hydrometer is graduated; in short, a salinometer should be simple in its construction, and certain in its action, and indicate at all times the exact degree of saltness of the water in the boiler. Thus the quantity of water necessary to be blown off might be regulated with certainty, and reduced to the smallest amount consistent with the safety of the boiler, and for economy of fuel. . . . .

"Long's Patent Salinometer is shown in section in Fig. 8. Mr. Long claims the improvement of attaching the cylinder A to the cylinder B, with a communication C, for the purpose of ensuring the safety of the hydrometer, and preventing its violent oscillation—perfect accuracy in testing the density of water is said to result, and the engineer is protected from danger by scalding. The cylinder A is connected with the boiler by the pipe and stopcock D, the pipe being closed at the top, and having openings E near the upper extremity. The water coming from the boiler, and passing the stopcock D, rises in the pipe, and flows through the opening F. The water falls into the cylinder A, passes through the opening C, and rises to the water level G, in both cylinders; H is an overflow pipe to carry off the surplus water, and to keep up a sufficient current to maintain the water to be tested at the required temperature. By turning the stopcock I, both cylinders can be discharged. J is a thermometer fitting in a slide, K is the hydrometer, L is the cover for closing the case when not in use, and I is a bracket for securing the instrument to the boiler, bulkhead, or other suitable place. This instrument affords a ready means of drawing water from a steam boiler under any pressure and temperature without any ebullition in the cylinder B, or oscillation to the hydrometer."

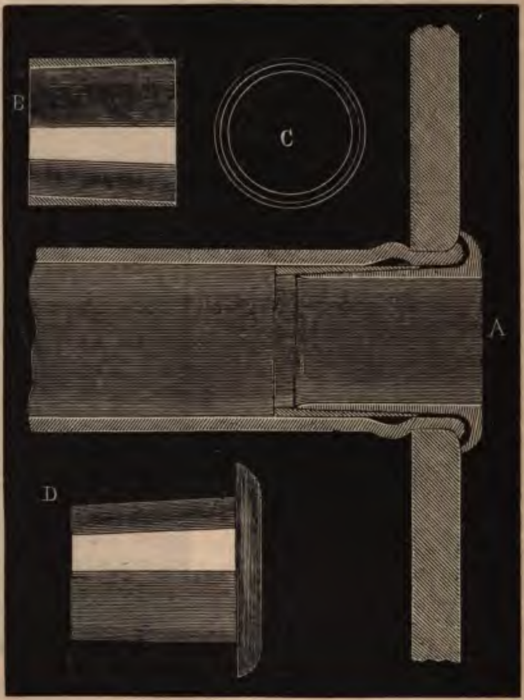
Fig. 8.



16. *Clark's Thimble for Boiler Tubes.*—In Fig. 9 we give

various views of this simple arrangement which has been in u in various steamers, and with great success. "Fig. A represen the combined ferrule in place, the object being to prevent leaka and guard against the evils resulting from expansion and co traction of the tube ends when hot and cold alternately.

Fig. 9.



"The common thimbles used for this purpose are of cast-iro and in a single piece; these are of iron or brass, generally iro and effect the object much more perfectly by expanding the tub *equally on both* sides of the sheet. The several figures, C, *and D, show the inside* and outside ferrules—one slipping with the other in an obvious manner. When a leak is found in the boiler the practice is to slip the inner ferrule, A, in the tube, previously coating it with cement composed of white and red lead. The outer thimble or gland. B, is then put in and driven home, when the tube is quickly expanded and the leak stopped. The tube will never after require calking, and may always be kept tight by this method. These ferrules do not interfere with sweeping the tubes at any time."—*Scientific American.*

17. *Wet Steam.*—On this important subject we give an abstract of an able paper given under date Oct. 13th, 1865, in the "Engineer." After pointing out that the use of wet in place of dry steam is the cause of a large annual loss of fuel, and adverting to those who have a difficulty to see what difference there can be or is between so-called varieties of steam, the writer proceeds:—"In one sense it is perfectly true that 'steam is steam' and nothing else; but that which passes into the cylinder of an engine is not always, nor even often, true steam. On the contrary it is a vapour saturated up to the very dew point, or holding in suspension free water either coming over directly from the boiler in the form of insensible priming or spray, or resulting from the condensation of a portion of the steam, either within the pipes of communication or the valve chest itself. It is absolutely impossible to procure steam otherwise than in a saturated condition from ordinary boilers without superheating apparatus, and even though the contrary were the fact, and steam perfectly desiccated, although unsuperheated, could be procured, the very performance of work within the cylinder, expended in propelling the piston, would suffice to abstract so much heat as would lead to the condensation of sufficient steam to render all the ramainder wet. The heat required to evaporate a single pound of water is equivalent to 745,812 foot pounds, and conversely, in practice for every 745,812 lb. raised one foot, 1 lb. of steam will be reconverted into water. If this work be performed in one minute it is equivalent to a minute fraction more than 22·6 horse-power; and we may, therefore, assume that for every 22·6 indicated horse-power exerted by a moving piston, 1 lb. of steam must be converted into water behind it per minute; and this, be it observed, without the aid of any cooling influence whatever. The heat latent in the steam is *transmuted* into work; we may have

either heat or work as we please, but we cannot have both together. The quantity of moisture thus produced is, of course, comparatively small; its influence is none the less important. The presence of a single drop of water within a cylinder is certain to induce the presence of two or three others; and the fact that a single pint of water per minute is deposited within the cylinder of a 20-horse engine will satisfactorily account for the consumption of possibly one-fourth more fuel than would otherwise suffice. There is nothing mysterious in this. In order to obtain the highest possible results from steam, it is indispensable that it should be kept as hot as possible; but the heat may escape in two ways, one tangible and evident to the senses, and therefore commonly observed and provided against; the other intangible, not apparent from external evidences, and therefore usually unthought of. The latter mode of escape is, nevertheless, infinitely the more important of the two. The first is merely radiation from the surface of the cylinder and pipes; yet unless the cylinder be exposed to currents of air, whether clothed or not, the loss from this source is comparatively trifling. By careful clothing it may easily be reduced to about 1 per cent., a quantity practically inappreciable. The other mode by which heat escapes is by a species of convection through the waste port into the condenser or the atmosphere. This has been expressed by saying that heat 'radiates' into the condenser, or the atmosphere. Such a statement is erroneous in every respect; no radiation in the true sense of the term can possibly take place round the angles of the passages permitting the steam to escape. The heat does not radiate. It is carried away bodily by the escaping steam, which absorbs it from, and thereby cools down, the metal of the cylinder and piston. It may here be asked, will not the steam carry away heat whether it be wet or dry? The answer must be in the negative as far as regards the cylinder. It is true that the steam in escaping will bring with it all the caloric proper to itself. If it be dry, its influence extends no further, because the gases, *when dry*, are the worst known conductors or absorbers of heat. The presence, however, of a very minute quantity of moisture suffices to render them the best known conductors, and in this lies the principal reason why moist steam is *wasteful of fuel.* With it the temperature of the cylinder can only be maintained by the expenditure of much steam at the commencement of each stroke, caloric being conveyed away to the condenser or the atmosphere with astonishing rapidity during the latter part of the exhaust. With perfectly dry steam, on the contrary, very little effect would be produced upon the metal, which would retain its temperature nearly constant during the exhaust, and would, therefore, not require to be warmed up again at the expense of the entering steam at the beginning of each stroke. It will be perceived, too, that if this warming up be effected by steam already saturated to its dew point, the least abstraction of heat must infallibly lead to the deposition of moisture on the metallic surfaces, and although a part of this will be re-evaporated during the latter part of the stroke subsequent to the closing of the cut-off valve, it is certain that the steam which fills the cylinder at the conclusion of the stroke cannot fail to be saturated. Whether the steam is absolutely dry or no, there is a constant tendency to the transmission of heat from the cylinder to the condenser. With true steam, which is analogous to a permanent gas in all its characteristics, the tendency is very feeble it is true, still it is obvious that, unless the fluid has a little free heat which it can spare in order to dry up the moisture due to the performance of the work, radiation proper, &c., it cannot leave the cylinder otherwise than moist, and in the fact that superheating supplies this spare caloric is to be found the principal reason why it is conducive to economy. The argument commonly brought forward in favour of the principle, viz., that water which would otherwise pass into the cylinder as such is evaporated, and the whole volume of steam thereby increased, no doubt possesses much force. Yet it is certain that this augmentation of volume cannot alone account for the excellent results frequently obtained from the use of the apparatus; and it is known, on the other hand, that the simple application of appurtenances by the aid of which the water was mechanically separated from the steam before it entered the cylinder, has led to a considerable saving of fuel in many instances. According to Dr. Haycraft's experiments, indeed, a saving of as much as 25 per cent. may, under exceptional circumstances, be realized by the aid of a proper separating apparatus alone.

The best means of drying steam has hardly yet been satisfactorily determined. Not only does a great difference of opinion exist as to points involved in the construction of superheating apparatus, properly so called, but even as to the place where the drying is to be effected as well. Shall we dry the steam before or after it enters the cylinder? In other words, shall we enclose the cylinder in a jacket of superheated steam, or shall we work superheated steam through it directly? No general answer can properly be given. Much must depend on the character, good or bad, of the boiler. If this last be given to priming and producing steam charged to excess with moisture, superheating apparatus cannot well be dispensed with; but with good boilers, working dry steam, jackets will answer a better purpose. It is very easy with the ordinary apparatus to overheat the steam, and thereby lead to the destruction of the valve faces, &c.; with the jacket this is hardly possible. The pipes or chambers commonly found in superheaters wear out more quickly than is desirable, and frequently give much trouble, especially when they are exposed to be suddenly cooled down by water boiling over into them during priming, and a leaking joint is of course intolerable in an apparatus exposed to considerable pressures. For these reasons, among others, superheaters are seldom used to supply jackets only, although high measures of expansion could be resorted to with the aid of these last alone, in nearly every case where the boiler is tolerably good. It is therefore worth considering whether or no very excellent results might not be obtained by superheating a portion of the waste steam, and filling the jackets with this. The heating might with safety be carried to almost any point in reason, and as the most moderate pressures would suffice, even fire-clay tubes might be used instead of iron in the superheater. As the loss of this steam could do no harm, a leak would be of very little consequence. As jackets are now used, a certain waste is inseparable from their action. Some steam must be condensed within them, in order that a great deal of steam may not be condensed within the cylinder. This would, of course, be saved by using the exhaust steam as we have suggested. Nor is it to be imagined that more condensing water would be required. On the contrary, as the whole quantity of steam passing through the machine would be reduced for the same power, the condensing water would also be reduced, and even were this not so it would be easy to withdraw only a certain portion of the exhaust steam for the supply of the jackets, the remainder being dealt with as usual. Any great refinement in the heating apparatus would be unnecessary; it would, therefore, be exceedingly inexpensive, both in construction and maintenance, while excellent results would undoubtedly follow on its use, especially in the case of engines having a long stroke, and running at a slow speed."

SECTION THIRD.

18. *Wear and tear of Boilers—Causes which deteriorate them—Preservation of Boilers.*—In this department the leading feature of the year was the reading of an elaborate paper—before the Society of Arts, London—by Mr. Fred. Arthur Paget, C.E., on "The Wear and Tear of Steam Boilers." Of this we now present an abstract to our readers.

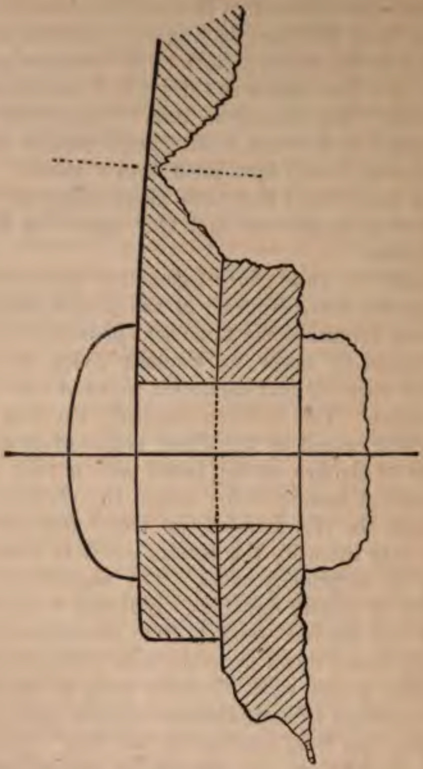
(*a*) "*The direct effects of the pressure of the steam.*—In calculating the working strength of a cylindrical boiler, the plates are assumed to be under a static load, and to be submitted to a tensile strain. The former of these assumptions is seldom, and the second is never correct. There are two principal causes that tend to exert impulsive strains on the sides of a boiler:—1. The sudden checking of the current of steam on its way from the boiler to the cylinder; 2. Quick firing, attended with too small a steam room; and both may sometimes be found to act in combination. . . . . According to Dr. Joule, the mere dead pressure of an elastic fluid is due to the impact of its innumerable atoms on the sides of the confining vessel. When the motion of a current of steam is suddenly checked, as by the valve in its passage from the boiler to the cylinder, its speed and weight cause a recoil on the sides of the boiler analogous to the effects of the, in this case, almost inelastic current of water in the hydraulic ram. This action is necessarily most felt with engines in which the steam is let on suddenly, as in the Cornish and other single-acting engines, working with steam valves suddenly affording a wide outlet, and as suddenly closing. It produces such phenomena as the springing and breathing of cylinder covers, and the sudden oscillations of gauges, noticed long ago by Mr.

Josiah Parkes and others. Some years ago, while standing on a boiler working a single-acting engine, and with a deficient amount of steam room, the writer noticed the boiler to slightly breathe with every pulsation of the engine. The same action has been observed by others with boilers the steam room of which is out of proportion to their heating surface. The intensity of the instantaneous impulses thus generated would be, as Mr. Parkes observes, difficult to measure, but their repeated action must rapidly affect the boiler at its mechanically weakest points. The more or less sudden closing of a safety valve while the steam is blowing-off would evidently produce the same effect; and this view is strengthened by the great majority of locomotive boilers—in which, while at work, there is no such sudden call on the reservoir of steam as in the Cornish engine—which explode while standing with steam up at the stations. It is not denied that in the case of a locomotive the mere extra accumulation of steam from the safety valves being screwed down above the working pressure will also come into play. But there can be little doubt that most boilers are subjected sooner or later, and with more and less frequency, to an impulsive load. This being the case, this consideration alone would demand a factor of safety of six in the designing of steam boilers.

"Emerson showed, more than sixty years ago, that the stress tending to split in two an internally *perfectly* cylindrical pipe, submitted to the pressure of a fluid from the interior, is as the diameter of the pipe and the fluid pressure. He also showed 'that the stress arising from any pressure upon any part to split it longitudinally, transversely, or in any direction, is equal to the pressure upon a plane drawn perpendicular to the line of direction.' As in a boiler the thickness of the metal is small compared with the radius, the circumferential tension has been assumed to be uniformly distributed; and the strain per unit of length upon the transverse circular joint being only half that upon longitudinal joints, the strength of the latter has been taken as the basis of the calculations for the tensile strength of the joints. But in taking the internal diameter of the boiler as the point of departure, the internal section has been assumed to be a correct circle, which would only be practically true in the case of a cylinder bored out in a lathe, and never in that of a boiler. Two of Emerson's corollaries from his first proposition have, in fact, been neglected. He shows that if one of the diameters be greater than another, there will then be a greater pressure in a direction at right angles to the larger diameter; the greatest pressure tending to drive out the narrower sides till a mathematically true circle is formed. The second is that, 'if an elastic compressed fluid be enclosed in a vessel, flexible, and capable of being distended every way, it will form itself into a sphere.' A number of proofs can be adduced that both these influences are more or less at the bottom of the wear and tear caused by the direct action of the steam.

"From 1850 to 1864 forty locomotive explosions causing a loss of human life have occurred in the United Kingdom. The Board of Trade reports in the Bluebooks presented to Parliament, and more especially those by Captain Tyler, R.E., probably form the most valuable and connected series of records extant on boiler explosions. This is more especially the case with regard to wear and tear caused by the direct action of steam unmasked by the effects of the fire, as the barrel and outside fire-box of a locomotive cannot be said to be under the direct action of the heat. Perhaps the vibration of the boiler through the motion on the line may intensify this action, but it is clear that vibration cannot be a primary cause. The majority of the reports are illustrated by careful drawings. Eighteen of the forty boilers gave way at the fire-box—eleven from the crown of the inside fire-box being blown down upon the tube plate; seven from the shells or sides giving way. Twenty burst at the barrel; and two may be ascribed to miscellaneous causes, from an originally defective plate, and from running off the line. Leaving out all those which occurred at the fire-box, as the majority of these might be ascribed to other influences than direct pressure, all the twenty explosions of the barrel could be traced either to internal furrows or to cracks, both running parallel with one of the longitudinal joints of one of the rings forming the barrel. All the joints which thus gave way were lap joints; and the furrows or the cracks (and the former greatly preponderate in number) occur at the edge of the inside over-lap, and, therefore, just at the point where the diminution of diameter caused by the lap-joint would be most affected by the pressure of the steam. (See Fig. 10.)

Fig. 10.



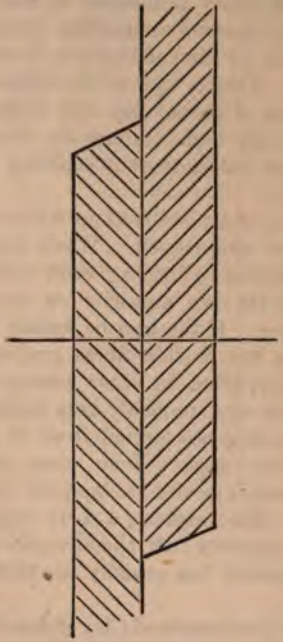
(Full size cross section of the furrowed longitudinal lap-joint in the fire-box ring of a boiler which exploded at Overton station, on the 30th May, 1864. It does not differ from other furrows.)

The plate at channels shows distinct traces of lamination through the cross-bending; and it is probable that plate of a good material will gradually laminate, while inferior metal will crack through in much less time. Nor are these furrows found with *only lap joints.* Butt joints, with a strip inside the boiler—and suspicion be entertained of its presence until an explosion, more or less serious in its results, reveals the dire fact. A great amount of ignorance prevails with regard to the quality of water used for raising steam, owing to the general difficulty in judging thereof. This is to be obviated by the proper use of chemical tests, but in too many cases the tests would have to be, and even are, applied by those lacking sufficient chemical knowledge to enable them to arrive at correct results. Hence, a course may be taken to remedy the evil, totally unsuited, if not opposed, to the necessities of the case.

"The ingredients in most waters are the same, differing only in their relative proportions, the principal constituents being the carbonate and sulphate of lime. But other ingredients are frequently found in combination, and exert a baneful influence upon the metal of which the boiler is made. Instances are not wanting of internal corrosion caused by the acidity of the water, which, in some cases, has been most virulent. Sometimes the whole plate is attacked, presenting a honey-combed appearance all over the surface, whilst at other times only small patches and some of the rivet heads are eaten into. We know an instance of a boiler plate having been reduced from an original thickness of 7-16ths of an inch to less than 1-16th from internal corrosion, the surface of the plate being honey-combed all over. A badly made boiler suffers severely at all the seams from the use of corrosive water. Small leaks, which, with a sedimentary water, might take up, are, with a corrosive water, found to enlarge their channel constantly, and to grow worse daily. In many cases where the use of acidulated water (as for instance, peaty water), is unavoidable, great benefit has ensued from the use of soda. By its adoption boilers have become tight which were previously very leaky and required constant repair. . . . .

"Unquestionably, the best method of preserving a boiler working under these conditions would be to use hard water for a time and allow the boiler to scale. If hard water could not be had, then chalk or lime or sulphate of lime might be added so as to form an artificial scale. The injurious results to the boiler arise from the purity of the water and the absence of lime salts. If the boiler scaled a little this water might be used. Hence, it is doubtful if pure waters are well adapted for steam boilers. The assume a spherical shape, from its ranges of elasticity and of tility being so short. But it may be said to be undergoing distinct stresses in as many directions. There is a stress a on the ends, and tending to rupture the boiler in two halve a direction parallel to the axis; there is the stress which is tension in a true circle, but which acts with a cross-bending s

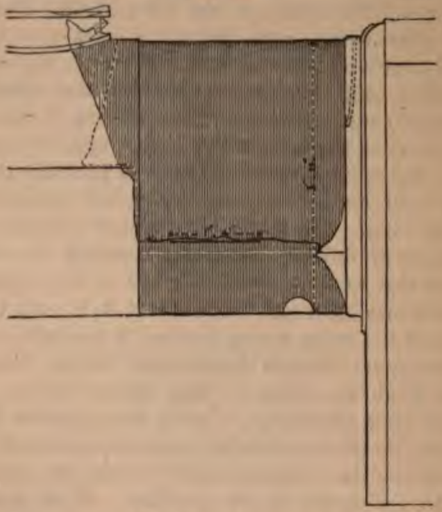
Fig. 11.



(The edges of the plates are cut to an angle of 65 deg. by means of inclined shears.)

in an ordinary boiler; and there is the stress which tends make it assume the shape of a barrel, or to bulge it out in centre of its length. The precise action on a material of sev *strains like this* is a portion of the strength of materials whi still completely unknown. Its probable effects may be illustrated by the ease with which a stretched india-rubber ring is cut through with a knife, or that with which a column under compression is broken by a blow from a hammer, or by the similar ease with which a tube under tension is split by a sharp blow; in fact, the operation of caulking a defective boiler under steam seems thus to often give it the finishing stroke which causes an explosion. The new boiler which burst from a defective plate at the Atlas Works, Manchester, in 1858, and that which burst through a crack at a longitudinal point last January, at Peterborough, both gave way while being caulked. This, again, accounts for the fact that adjacent boilers sometimes explode one after the other, pointing, at the same time, to the danger into which a sound boiler may be thrown by an explosion. Upon the same principle it is probable that the modern guns, built up from strained rings, will be easily put *hors de combat* by shot. The probability is that a number of simultaneous strains in different directions diminish the elasticity of the material that would allow it to yield in any given direction. However this may be, it will be seen that it is only the pressure on the ends of the boiler acting parallel to the axis, and tending to tear the cylinder through transversely, which bears fairly on the riveted joint, or, rather, on that metal between the rivets which is left after punching. Unless the cylinder be perfectly correct inside, the circumferential strain resolves itself into cross-bending, shifting the dangerous section from the iron left after punching to the metal at the over-lap. With respect to the stress tending to bulge the cylinder in the centre, it is clear that if we suppose a strip cut out from the entire length of the boiler, each portion of the length of this strip could be regarded as a beam under an uniformly distributed load. As, however, with the lap joint, there is a double thickness of metal transversely, that joint is the strongest and stiffest portion to resist the stresses tending to bulge out the cylinder in the middle, and also to tear it in two halves. This affords some justification for the belief of old boiler makers, before riveted joints were tried under a direct tensional load, that the joints are the strongest parts of the boiler. And, indeed, this is what we find in practice. The thinnest portion of the longitudinal furrows is generally exactly in the middle of the plate, and this is caused by the longitudinal stress, which is acting at right angles to the transverse cross-bending stress. A strip cut from joint to joint is, in one respect, in the condition of a beam supported at both ends, uniformly loaded throughout its length, and, according to known principles, therefore giving way in the middle. (See Fig. 12.

Fig. 12.



(From Captain Tyler's report, dated 30th June, 1864, on the boiler explosion at the Overton station of the London and North-Western Railway. The plate torn off is shaded, the course of fracture on the other side of the boiler is dotted, while the furrow is shown by the thick horizontal line.)

"It is impossible to deny the existence of an infinite number of stresses acting on the sides of a vessel undergoing fluid pressure, producing what, for want of a better term, might be called a 'bulging strain.' Instances of this action may be noticed in the sketch of the leaden pipes given by Mr. Fairbairn, which were bulged out in the middle by internal pressure, as also in the fire-box sides influenced by the same means, and in the centre of the surface. Unaccountably enough, the effect of such a strain on the ultimate resistance, and, above all, the elasticity of materials, has been entirely neglected by investigators, and there are no published data on the matter. The effect of the internal pressure is evidently resisted by a double thickness of plate at the joints, so that the load on the middle of a single ring may be considered as determining the weakest part of the boiler.

"To construct a general rule or formula that would take into account the distorting effects of the lap or of the welt of butt joints would be impracticable; but it is clear that the usual mode of calculating the strength of a cylindrical boiler from the tensile strength of joints tested by weights, or hydraulic pressure directly applied, is far from being correct. It is only tolerably correct with scarf-welded joints, or with butt joints with outside welts. Even here, the hoop tension of the true cylinder is resolved with a cross bending strain if the cylinder does not form a correct circle internally. The usual formula would be practically correct, if the boiler were prevented from altering its shape during the impulses sometimes given by the steam, and the quieter buckling action caused by the alternate increase and fall of the pressure. In fact, a boiler, like a girder, does not merely demand a high ultimate strength, but also a stiffness which is the protection against alternative strains, against buckling or collapse.

"Disregarding the effects of the thickness of the material, a perfect cylinder should, theoretically, afford the same ultimate resistance, whether exposed to external or internal pressure. Its resistance to collapse should, indeed, be greater, as most materials give more resistance to compression than to tension. This is not the case, as the distortion of form progressively weakens an internal flue by increasing the load on its surface, while the contrary is rather the case with the boiler exposed to internal tension. Before Mr. Fairbairn showed the inherent weakness of flue tubes, their frequent explosions through collapse were ascribed to spheroidal ebullition and other similar causes. They are now, according to the engineer of the Manchester Boiler Association, stronger than the shells, by means of the T-iron and angle iron bands now generally used, and also by the excellent seams introduced by Mr. Adamson so long ago as 1852. While T-iron and other bands could be used for the barrels of boilers not exposed to the fire (as is recommended in France and by the

Board of Trade inspector of railways), Adamson's seams reversed would probably form excellent transverse joints for a shell fired from the outside, and, with a boiler like this, thin and narrow plates could be used, affording a stronger and tighter lap joint. With a construction of this kind little or no deflection or bulging could occur, and the sectional area of the plate and the rings would really give the strength of the boiler.

(*b*) "*The Mechanical effects of the heat.*—While a maximum of stiffness to the mechanical action of the pressure is required in a steam boiler, a maximum of flexibility to the irresistible mechanical force of heat is of no less importance. For instance, a great advantage of some of the forms of strengthening rings for internal flues is that they allow the use of thinner plates; together forming a structure of great flexibility to complicated thermal influences. The longitudinal expansion of inside flues like this is taken up by a slight spring or swagging at each joint, and the end plates of the shell are not unduly strained by the combined effort of the internal pressure and the expansion due to heat. This is one way in which defective circulation, or a sudden current of cold air or of water, can act on the structure, by unequally straining the plates; and, although it seems probable that the effects said to have been thus produced are, to some extent, due to other causes, they point to the importance of keeping the temperature of the plates as low as possible. One protection against effects of this kind is the gradual diffusion of heat, produced by its conduction to and from the different plates. It is a general belief with engineers that a pressure of steam strains a boiler more than cold hydraulic pressure; but it is unsettled as to what amount and in what exact way. The basis of an examination of the kind would have to be sought in an exact determination of the temperature of a plate which is transmitting the heat to the water, and this has not yet been determined with any accuracy.

"While it is certain that boiler plates can assume very high temperatures, even up to red-heat, authorities differ as to the diminution of ultimate strength which is caused by heat, while its effect on the elasticity of the plate has been scarcely attended to. The experiments on the ultimate tenacity of iron at high temperatures, conducted by Baudrimont, Seguin, and the Franklin Institute, can scarcely be looked upon as of much value, for they were made on a very small scale, and with no regard to the temporary and permanent elongations—or to the effect of heat on the elasticity and ductility.

"Mr. Fairbairn observed no effect on the strength of plate iron up to almost 400 deg. Fah. At a 'scarcely red' heat the breaking weight of plates was reduced to 16·978 tons from 21 tons at 60 deg. Fah.; while at a 'dull red' it was only 13·621. MM. Tréméry and P. St. Brice, aided by the celebrated Cagniard Latour, found that at nominally the same temperature (*rouge sombre*), a bar of iron was reduced in strength to one-sixth of its strength when cold. This is much greater diminution of strength than that found by Mr. Fairbairn. Apart from other causes, this might easily be due to the fact that incandescent iron affords a different tinge during a dull day to what it does in a clear light. In fact, the great impediment to all these investigations is the want of a thermometer for high temperatures; but M. Tréméry's result is perhaps more conformable with daily experience. Mr. Fairbairn's data would show that the ultimate strength of wrought iron is reduced about one-half; But M. Tréméry's result explains the generally instantaneous collapse of flues when red-hot, and which have been of course originally calculated to a factor of safety of six.

"A most important question is the effect of temperatures, whether high or low, on the elasticity of the material—whether iron will take a permanent set with greater facility at a high temperature?

"There is, however, another very important point with respect to wrought-iron which has scarcely received the attention it deserves. As would appear from a number of phenomena there seems to be a sort of thermal elastic limit with iron. When heated, and when its consequent dilatation of volume does not exceed that which corresponds to, perhaps, boiling point, it returns to its original dimensions. Beyond a certain temperature it does not contract again to its pristine volume, but takes a permanent dilatation in consequence, apparently, of its elastic limits having been exceeded. A number of experiments by Lt. Col. H. Clerk, of Woolwich, on wrought-iron cylinders and plates, bear distinct evidence to a *dilatation* of volume in wrought-iron, when repeatedly heated and suddenly cooled. In experiment 7, for instance, 'two flat pieces of wrought-iron, each 12 in. long, 6 in. deep, and ½ in. thick, were heated and cooled twenty times, one being immersed one-half, and the other two-thirds, its depth in water. That immersed one-half contracted or became indented on the ends fully 3 in.; the other had similar indentations, but only to one-half the amount. They both turned up into the form of an arc,' the convex side of which appeared in the portion heated and cooled. Unfortunately, the specific gravities of the different portions were not tried by Col. Clerk. A succession of trials of the kind produced cracks in the metal, thus explaining how boiler plates are cracked by imperfect circulation and by cold feed-water let in near the fire; and the thicker the plate, the more permanent dilatation of volume, and consequent danger. Mr. Kirkaldy found that 'iron highly heated and suddenly cooled in water, is hardened,' being injured, in fact, if not afterwards hammered and rolled. In fact, a very general belief exists that very ductile good iron, used in the form of a steam boiler, soon gets brittle. There are some applications of metal to a steam boiler peculiarly liable to be strained beyond the limits of elasticity; by mechanical force, by the mechanical force of expansion and contraction, and by dilatation of volume through heat, all three acting simultaneously. Such is the case with fire-box stay bolts. Accordingly, they are found to get very brittle when of wrought-iron—which is a much less ductile metal than copper. Mr. Zerah Colburn states that he has 'frequently found these stays (where made of wrought-iron) to be as brittle, after a few years' use, as coarse cast-iron.' He has 'broken them off from the sides of old fire-boxes, sometimes with a blow no harder than would be required to break a peach stone.'

(c.) *The Chemical Effects of the Incandescent Fuel.*—"Whatever physical changes may be induced in iron by the long continuance of a high temperature which is not succeeded by the application of the impact of the hammer or the pressure of the rolls, it is certain that long-continued red heat leads to the loss of its metallic consistency. Its surface gets converted to a greater or less depth into forge scales, which, according to Berthier, consist of a crystallized compound of peroxide and protoxide of iron. The mechanical action of the gases—and especially of the free oxygen contained in every flame—forced at a high velocity by the draught past the more or less heated plates, would also aid these chemical combinations—upon the same principle as iron filings, thrown through a gas flame, burn in the air; and upon the same mechanical principle as the incandescent line is worn away by the flame of the oxyhydrogen blow-pipe. These actions would take place with any fuel, even with pure charcoal, but when mineral fuel, which mostly contains more or less iron pyrites, is used there is much more danger to the plates, especially over the fire, in getting red-hot, as the flames would then hold sulphurous acid, and often volatilized sulphur. A familiar illustration of an action of this kind is afforded by the fact that a piece of red-hot iron plate can be easily bored through by means of a stick of sulphur, the combination forming sulphide of iron. Dr. Schafhaeutl, of Munich, has given great attention to the changes in plates subjected to the action of fire; twenty-five years ago he read a paper before the Institution of Civil Engineers, and more recently he has published an essay, both on this subject, in a Munich periodical. He has brought forward a number of facts, founded on chemical analyses of plates of exploded boilers, showing the danger due to chemical action alone when the plates of a boiler become red hot. He notices that the iron of the inside of the plates in getting red hot decomposes the water, and combines with the oxygen thus freed. It also loses some of its carbon. The outside combines with the free oxygen, and with any sulphurous acid in the flame. He states that iron made with pit coal is much more affected than charcoal-made iron, becoming laminated at the original joints in the pile out of which the plate has been rolled. It is possible that portions of oxide are carried into these joints, and it is, at any rate, certain that iron gives way easiest at these places. This points to the great value of really homogeneous plates, such as those of cast-steel, in which homogeneity has been obtained by the only known means of fusion. The remarkable diminution of elasticity and of tenacity caused by the combination of the red-hot iron with sulphur—the absence of all elasticity and tenacity in the oxides of iron—show that, even if a flue do not at once collapse, or a shell explode, through getting red-hot, the boiler is more or less injured every time it gets over-heated. A defective circulation, by permitting such a temperature as to drive the water off the plate, would soon lead to local injury. Particular spots in externally-fired cylindrical boilers are sometimes, as is stated by Mr. L. Fletcher, of Manchester, thus affected, and in an apparently mysterious way. A new boiler, in which a heap of rags were accidentally forgotten, had the spot burnt out in a few days, doubtless through the resulting defective circulation and its consequences. The plates just above the fire of internal flues also suffer in this manner. It is, perhaps, possible that turned joints, secured by bolts, and allowing an occasional reversing, or rather rotating, of the ring, might, in some cases, be here of service. At any rate, universal experience proves that the thicker the plate the easier does it get red-hot, and these chemical facts also point to the desirability of a minimum of thickness. In fact, the wearing away of the plates through these causes, if mechanically strong against pressure, often gets arrested at a certain thickness. In Germany and France, some of the best manufacturers still make the plates over the fire of, for instance, inside flues, slightly thicker than anywhere else; but the combined chemical and mechanical actions of the heated fuel cause most wear and tear in a thick plate, and thus justify American practice in this respect. In that country fire-box plates of good charcoal iron are made only $\frac{5}{16}$ or $\frac{1}{4}$ of an inch thick, and with stays 4 in. apart, give good results under nearly 150 lb. steam pressure.

(*d.*) *The Chemical and Physico-Chemical Effects of the Feed-water.*—"The wear and tear of a boiler which occurs in the form of corrosion, properly so called, may be divided into two principal kinds:—(1) internal; and (2) external; and the progress of both is necessarily intensified by the mere effects of temperature. Each, however, has its strongly-marked, distinct, character —not merely as to position, but also as to origin and results.

"A steam boiler is in the position of a vessel into which large volumes of water are continually forced; while the heat applied, driving off all volatilizable matter, leaves behind a concentrated solution with a chemical character dependent on that of unvolatilizable matters in the feed-water. The specific gravity of the substances found in the water naturally causes them to sink towards the bottom, at which part the solution is generally more concentrated, however much it may be stirred up by the ebullition. Mr. J. R. Napier lately stated that a piece of zinc 'about 4 ft. long, by 3 in. broad, by $\frac{3}{16}$ths thick, placed in a marine boiler for three weeks' to a depth of 18 in. in the water, showed a corrosion which rapidly decreased 'up to the highest part, which, in the steam, appeared to be little affected.' This accounts for the fact that all boilers, even those internally fired, like locomotive boilers, have their plates most affected towards the bottom, and that internal corrosion always shows itself to a greater extent below the water line. The *bouilleur* of the form of boiler known as the French boiler is also generally more affected than any other part. To resist this sort of slow action, it is clear that the more the bulk of metal the better, and it is for this reason that the bottom plates of most marine boilers are made thicker, while these same plates in locomotive boilers have to be often renewed. Any chemical or physico-chemical action of the kind is of course intensified by temperature, and this is one of the causes that externally-fired boilers give way most a little in front of the furnace. But the plates above the water-line also get more or less corroded, and not merely with the usual character of rusting, but in that peculiar form known as pitting, which generally shows itself much more strongly marked below the water-line.

"The presence of a concentrated solution of an acid or alkaline character, kept at a high temperature for years in contact with iron plates, would be sufficient to account for much corrosion. But the internal corrosion of steam boilers has many features of such a mysterious character that no accredited explanation of its attendant phenomena has yet been put forward. In the first place plates thus attacked show a number of irregular holes like a pock-marked human face, or like the small craters seen on the moon's surface. The writer has also sometimes observed two or three little irregular excavations like this in a plate otherwise showing a large surface quite intact. Sometimes the plate is most pitted round a projecting bolt; at others, one plate will be perfectly sound, while that riveted to it will be almost eaten away, both having been the same time at work, and under, of course, apparently exactly similar conditions. With locomotive boilers this pitting has been ascribed to galvanic action between *the brass tubes and the iron* plates.—But it is notoriously well known to locomotive superintendents that boilers with iron tubes are often worse pitted than those which have run the same distance with brass tubes. Besides, all iron boilers, with or without brass, whether used for stationary, locomotive, or marine purposes, are subject to pitting.

"An explanation which seems to meet all the circumstances of the case is the following:—Mr. Mallet, in a report addressed to the British Association some years ago, showed that wrought-iron and steel (blister steel probably), 'consist of two or more different chemical compounds, coherent and interlaced, of which one is electro-negative to the other.' In fact, ordinary wrought iron, being also welded up from differently worked scrap, is far from being an electro-homogeneous body. In a boiler, the hot water, more or less saturated with chemical compounds, is the exciting liquid, and the electro-positive portions of the plates are thus quickly removed to a greater or less depth. This explanation meets most of the known circumstances with respect to pitting; it even, in a great measure, explains how plates above the level of the water, especially in marine boilers, get very rapidly corroded in portions, while another part of perhaps the same plate is scarcely affected. The concentrated water in a marine boiler is known to be generally acid. 'Of all the salts contained in sea water,' says Faraday, 'the chloride of magnesium is that which acts most powerfully' on the plates. He shows that a cubic foot of sea water contains 3·28 oz. of this salt; and, at the same time, points to the danger of voltaic action in a boiler through the contact of copper and iron. In a smaller degree the contact of cast with wrought iron, or between the different makes of wrought-iron in the same plate, or between contingent plates, acts in the same way. It is not improbable that some hydrochloric acid is present in the steam of marine boilers. 'M. J. C. Forster has tested some of the condensed steam from the safety-valve casing, and from the cylinder jacket of the Lancefield, and found both decidedly acid.' With an exciting liquid in the condensed steam, it is thus explicable how the plates of marine boilers often get corroded in a most capricious manner, while, at the same time, the current of steam would create a certain amount of friction on the oxide, clearing it away to act on a fresh surface.

"The crucial test of this explanation of pitting would be the observation of the absence of the phenomenon from plates of an electro-homogeneous character. The homogeneity could only be expected from fused metal, such as cast-steel. Accordingly, while the writer was in Vienna a short time ago, he was assured by Mr. Haswell, the manager of the Staatsbahn locomotive works, that some locomotives made of cast-steel plates in 1859, for the Austrian Staatsbahn, had been working ever since without showing signs of pitting, though under similar conditions iron plates had severely suffered in this way. Pitting may thus be fairly defined as a form of corrosion localised to particular spots by voltaic action. It is also probably aggravated through the motion of the plate by mechanical action, and the expansions and contractions through alternations of temperature. All boilers are most pitted near the inlet for the feed-water, and with inside cylinder locomotive boilers there is generally more pitting at the smoke-box end—no doubt caused by the more or less racking action on these plates. A state of corrosion at particular spots would probably be kept up to a greater intensity by the incrustation being mechanically thrown off. With a quicker voltaic action, caused by any unusual intensity of the exciting liquid, the sides of the cavities in the plates would be sharper and less rounded off; as in the case of the boiler fed with mineral water from ironstone workings, which exploded last year at Aberaman, South Wales.

"The fact that pitting occurs in marine boilers when distilled water from surface condensers is used, does not affect this explanation. Fresh water, from whatever cause, after repeated boiling, is stated to carry the salinometer even higher than sea water, thus proving that it is not pure. In the next place there is the absence of incrustation, which to some extent always protects the plates of boilers from the chemical action of its contents. In this way the mechanical buckling of the plates—directly and indirectly causing the furrows we have spoken of—by continually clearing particular lines of surface from incrustation and oxide, reduces these particular spots, with respect to corrosion, to the condition of the plates of a boiler fed with water which deposits no incrustation. Corrosion will also act more rapidly at a furrow through mere increase and renewal of surface. To resist that form of internal corrosion specially known under the name of pitting, a maximum of electro-homogeneity is evidently required in all the component parts of the boiler."

(*e.*) *The Chemical and Physico-Chemical Effects of the Feed-water.*—"While the action of internal corrosion, often very equally corrugating the plates over a large surface, as a rule scarcely, at any rate only gradually, affects their mechanical strength, external corrosion, being localised to particular spots, is of a much more dangerous character. The one is gradual and easily perceptible, while the other is rapid and insidious in its progress. Apart from accidental circumstances affecting the brickwork on which a stationary boiler is erected, or the outside of the bottoms of marine boilers, it is clear that external corrosion can only occur through leakage. When leakage takes place through a crack in the plate, caused by mechanical action, or at a hole burnt out by heat, the effects of leakage are only secondary results, due to a primary cause, which of itself may cause the stoppage of the steam generator. But a leakage at a joint may in itself gradually cause the destruction of the boiler. Here we see another reason that the character of a boiler, not merely as to ultimate strength, but also as to wear and tear, intimately depends upon the form of its joints. It is often noticeable that very good lap joints, even when tested under hydraulic pressure up to only 50 per cent. above the working load, sweat more or less. The tendency of the internal pressure to form a correct circle bears indirectly on these joints, causing them to open, more or less, and to leak, in spite of the caulking. Mr. Robert Galloway, C.E., who, as an engineer surveyor of long standing of the Board of Trade, has, probably, made more than three thousand careful inspections of marine boilers, states that he has often noticed a furrow or channel on the outside of the joint, running parallel to the outside overlap for some distance, and evidently caused by leakage. Along the water line condensed water will act on the joints, while below it the concentrated contents of the boiler will come into chemical action. A leakage in a marine boiler often eats away a $\frac{3}{8}$ in. plate within a year. In some cases a jet of hot water from a leakage has a frictional action; in fact, even with such an incorrodible and hard substance as *glass* an effect like this has been perceived, and a slight leakage continued during several days sometimes produces a noticeable furrow on a glass gauge tube. With sulphurous fuel, a powerful chemical action will come into play on the plates. One volume of water takes up about thirty volumes of sulphurous acid gas; and these sulphurous fumes of the fuel, coming in contact with the water from a leakage, will be more or less absorbed. An acid mixture like this must quickly eat away the plate. It is certain that a leakage acts much quicker on a boiler fired with sulphurous fuel than on one fired with wood. M. G. Adolphe Hirn has observed a plate, nearly seven-eighths thick, to be pierced, in the course of time, as with a drill, by means of a little jet which struck it after passing through a current of hot coal smoke."

The next point taken up by Mr. Paget was *the Legislative Enactments.* This, for reasons stated at the time, we published in last year's volume for 1864 in par. 22, p. 103, to which, therefore, we refer the reader.

19. On the subject of *Hydraulic Testing of Boilers* we gave expression (in par. 15, p. 67, vol. for 1864), to certain opinions. These we see no reason to change. Sundry opinions of others we gave also at the same time, to which we refer the reader. In the paper by Mr. Paget (see last par.), we find the subject also considered, from which we take the following:—"Although, as we have seen, the application of a known amount of hydraulic pressure is in such general use for the determination of the strength of a boiler, there are, nevertheless, few points in engineering about the real value of which there is so much dispute. Everybody seems to have a different opinion on the matter. Some say that the hydraulic test is the only means of determining the strength of a boiler; others that it is a very injurious and useless measure. As to its amount, some recommend one and a-half, many twice, some thrice, and a few even four times the working pressure. While numerous engineers advise its application to old boilers, others have strong objections to its use in this way. Whether the force-pump be really the best apparatus for its application, is, with other questions, also placed in doubt. The truth is that, while on the one hand, like other tests, it may be abused and wrongly applied, on the other its value may also be exaggerated.

"*The best practical proof* of its necessity for new boilers is afforded by the fact that explosions have occurred the first time steam has been got up—such as that at the Atlas Works, Manchester, in 1858. Unless every plate be separately tested up to proof load it is impossible to be certain whether one of them is not defective. This function is clearly much better performed by the hydraulic test. Then, as to its application to old boilers, much can be learned during internal examination; but it is not always possible to tell the remaining thickness of the plates by this means, nor their deterioration through the heat. It is often said that a successful resistance to the hydraulic test is no proof that the boiler might not have been burst by a few pounds more; and that it may so suffer as to perhaps afterwards burst with a less pressure of steam. But this is no more true than it is true of a girder, for instance, which has withstood without permanent deflection its proof load. In every case it is necessary that its effects on the boiler should be exactly ascertained. In fact, the real test consists in this examination, and the proof pressure is only a means to this end. The boiler should, if possible, be subjected to a careful internal and external examination. With locomotives this can only be accomplished by taking out the tubes; with ordinary land boilers it can only be done by removing the brickwork. In fact, it may be said that a steam boiler is never absolutely safe which cannot be easily examined—more especially from the inside. But by gauging the flue tubes, the combustion chambers, the flat surfaces, and even the barrels, it may be ascertained very nearly whether the limits of elasticity of the material have been exceeded—whether, therefore, the pressure has additionally injured a boiler which was near rupture already. It is often very plausibly observed that there is great danger in testing a boiler, which cannot be examined internally, to double, or even to only one and a-half the working pressure. It is said that the test may strain the boiler without its showing any outward indication. It is certainly just possible that such a case might happen.

"An objectionable plan in measuring the pressure applied, and, for several reasons, one likely to lead into error, is estimating it from the load on the safety valve lever. A metallic gauge should be used, and very neat pocket instruments of the kind *are sold in Paris.* In frosty weather the rivet heads are liable to be snapped if the metal be not somewhat warmed by using hot water. The hydraulic ram kind of action on the sides is also much less likely to occur if a rather narrow force pipe be used for the pump.

"There can be no doubt that it would be a valuable thing to be able to employ some means of measuring the permanent and the temporary extension of volume, if any, produced by the hydraulic test. It is probable that a boiler, as it gets old, and takes a permanent set under the pressure, also increases in volume; so that it doubtless holds a few gallons more than it did when new. An ingenious plan for measuring the increase of volume is recommended in the Bavarian regulation. After the boiler is filled the amount of water forced in is measured by pumping it from a vessel marked with divisions. When the pressure is removed the boiler contracts more or less, forcing out at least a portion of the water; the amount remaining is supposed to give the dilatation of volume of the boiler. The difficulty in the use of this plan would probably consist in the presence of air in the water itself, and any which might chance to remain in the boiler. That in the water might be greatly diminished, or at any rate brought down to a constant amount, by boiling; but there would be no precise security against any air in the boiler, and as the weight of air absorbed by water (according to a well-known law) is in proportion to the pressure, it would be taken up by the water, thus falsifying the indications when the pressure was removed. On the other hand, a high temperature of the water would form an impediment to this absorption. The experiment is certainly worth trying. It might be very valuable with tubular boilers inaccessible from the inside, as any permanent set or deflection ought to be indicated by little or no water being compressed out by the contraction of the boiler on the removal of the pressure. As long ago as 1844, M. Jobard of Brussels, in order to obviate the supposed injurious effects of the hydraulic blow of the water on the plates, proposed to fill the boiler with water, first loading the safety-valves, and to then dilate the water, and consequently the boiler, by means of heat applied to the outside. More recently, Dr. Joule of Manchester has used the same plan himself, proposing it for general adoption. In addition to the loaded safety-valve, he used a metallic pressure-gauge 'to be constantly observed, and if the pressure arising from the expansion of the water goes on increasing continuously without sudden decrease or stoppage until the testing pressure is obtained, it may be inferred that the boiler has sustained it without having suffered strain.' Another plan, also founded upon the same principle of the irregularities of extension of metals when the limit of elasticity is exceeded, has lately been proposed. This consists in bringing an ordinary steam-engine indicator in communication with the pump-plunger, as if it were a steam-engine piston-rod. The ordinates of the pencil diagram would thus give the pressure in the boiler, while the respective abscissæ would give the quantity of water pumped in at each stroke. As long as the limit of elasticity was not exceeded there would be a horizontal line, while a curved line would appear as soon as the sides began to take a permanent deflection. There seems to be a sort of contradiction in depending for results like these upon such irregular appearances as the extensions beyond the elastic limit. But all these proposals are undoubtedly worth trial in practice. Dr. Joule's plan has the merit of affecting the plates by both heat and pressure—thus bringing them under every-day conditions."

The publication of Mr. Paget's paper, of which in this and the last par. we have thus give a resumé, gave rise to a rather lively, and certainly lengthy discussion, more especially between its author and Mr. D. Kinnear Clarke, the well-known writer on Locomotive Engineering; so lengthened, indeed, that our space utterly precludes taking up the matter, even in the most condensed form, although, doubtless, much suggestively practical information was elicited during the discussion which would have been interesting to our readers. We can therefore only refer them to the pages of the "Engineer," where the letters were published.

20. (*a*) *The Corrosion*, (*b*) *the Incrustation, and the* (*c*) *Preservation of Steam Boilers.*—In the "Mechanics' Magazine," under the respective dates of Feb. 24th, March 3d, and March 10th, 1865, three articles on the subjects above noted were published. In each article the subject was fully and fairly treated,—so fully, indeed, that we can only give a brief abstract of what was said, referring our readers to the articles themselves for fuller information. And *first*, as to the (*a*) *corrosion* of boilers. "Corrosion may *go on for years, either* internally or externally of a boiler, and no

been pursued by one of the London water companies for many years with perfect success. Mahogany sawdust has been employed with advantage for the same purpose as the oak logs. It acts in two ways—first, mechanically, by offering so many small points on which the carbonate and sulphate of lime may be deposited, and secondly, by a peculiar action of the extractive matter in the wood. This applies more particularly to oak, especially when green, in which state it should be used. In North Wales the water used in boilers is often perfectly green, and oak sawdust is administered in considerable quantities. Chloride of ammonium will convert the lime salts into soluble compounds, viz., sulphate and carbonate of ammonia, and chloride of calcium; but in practice its use has not been very successful, owing to the sal ammoniac and ammoniacal salts acting on the brass-work. Where the action of a cure is only partial, as is the case with some boiler fluids, the remedy is worse than the disease. For instance, in some boilers at Woolwich supplied with Thames water, a certain composition was used in the hope of preventing incrustation. It was found that the composition only acted upon the lighter portion of the sediment, leaving untouched the heavier and harder portion, which, though forming a much thinner deposit, was nevertheless impenetrable to the water, whilst, on leaving the lighter and the heavier ingredients undisturbed, they were found to form a porous substance through which the water could reach the plates.

"Prevention is at all times better than cure, and under ordinary circumstances, where the construction of the boiler does not insure immunity, the most practical plan for the prevention of incrustation is the adoption of an efficient mode of blowing-out. A more complete remedy, however, exists in the adoption of what is termed dry, or surface condensation. But the benefits to be derived from judicious blowing-out are not generally realised, or there would not be the irregularity there is in the use of the blow-out apparatus. To be effectual in its operation it should be used at regular intervals during the day, the best time being whenever the engine is not at work and the water therefore at rest. Under these conditions the sediment has an opportunity of settling, whereas at other times it will be held in suspension by the rising bubbles of *steam*, when blowing-out will be com-addition of a small amount of lime salts is beneficial, as by being deposited on the iron they preserve it. But in large quantities these salts become prejudicial by forming an incrustation. The alternate use of soft and hard water would prove advantageous. In many cases where corrosion has taken place in boilers where surface condensers are used, it may be attributed to small particles of the copper or brass from the tubes of the condenser being carried into the boiler, and not, as is often supposed, to a galvanic action originating in the condenser. In fixing surface condensers, care should be taken that all filings and other loose particles of the tubes should be entirely removed.

"External corrosion arises generally from external damp, which is caused sometimes by water penetrating into the flues and saturating the seating, and sometimes from blowing seams and rivets. The injurious effect upon the boiler is much accelerated when in contact with the brick-setting, which frequently retains the water, and holds it against the plate, the result being rapid oxidation. Boilers are most liable to external corrosion when set on mid-feathers. 7-16th in. plates have been reduced in this way to 1-8th in. thick. This external corrosion is more easily prevented than cured, and prevention lies in having, in the first instance, thoroughly good material and work, both in the manufacture and setting of the boiler. Equal care should be taken to secure the completeness and perfect arrangement of the fittings, inasmuch as the blow-out apparatus and the lower man-hole joint in front of the boiler, when not well made, are frequently the cause of damp ash-pits, from which serious cases of corrosion have resulted. Similar consequences arise as well from the discharge from the glass-water gauges. Channelling has been supposed to be the result of oxidation caused by a slight leak at the joint. This, doubtless, holds good in some cases, but many instances occur where no external damp can be discovered, and on separating the plates no trace of leak can be detected.

"In a marine boiler external corrosion takes place in the region of the steam-chest by the dripping of water from the deck; the bottom of the boiler is corroded by bilge-water, and the ash-pits by the practice of quenching the ashes with salt-water. But *these sources of* injury are easily remedied. A felt covering, blowing-out. And in noticing the benefit of this he draws attention to the fact that the *fittings* of a boiler connected with the blowing-out apparatus are, as a rule, very generally uncared for. "Great carelessness," he says, "is frequently evinced with respect to blow-out taps and valves, and cases are not wanting in which a criminal recklessness has been displayed. The apparatus generally used consists of slides, mushroom valves, wing valves, and taps. With respect to sluices or slides, the experience is that they work freely, but they will not always close perfectly, so that it may, and in fact does, at times happen that they are accidentally left open. The safety of the boiler is thus imperilled, as the water is brought down very rapidly. It sometimes occurs, too, that they cannot be closed, owing to the sediment becoming lodged in the bottom of the slide or sluice boxes. The mushroom valve is readily opened and permits a free escape, but it is often found that particles of scale blown out with the water effectually prevent the reseating of the valve, which has frequently led to their disuse. The most satisfactory is the wing valve, which is found to work in an efficient and regular manner. The use of cast-iron taps is to be deprecated; they often corrode, and, sticking fast, are utterly useless. Those made of cast-iron in the shell and brass in the plug are liable to draw back in working. They often give trouble in consequence of the unequal expansion of the metals. They are generally difficult to close if opened when steam is up, which jeopardises the furnace crowns, so that where such taps are fitted their use is frequently limited to the occasional emptying of the boiler. The description of taps found to give the most satisfaction in general use are those made wholly of brass both in the plug and shell, and fitted with glands and packed. There is a greater safety in their use than in that of the common plug tap, in which the fastening often gets loose, and on opening the plug flies out, severe scalding being the result. Cast-iron taps having the plug and shell bushed with brass are found to work well, although it is a question whether, on the whole, they are more economical than those made of brass throughout. Long levers for opening and closing the taps should be avoided, as they strain them and often lead to fracture. The arrangement for carrying off the water too, is often very inefficient; a proper waste pipe should always be attached, otherwise the pro-water. The carbonate in precipitating forms a loose powder, but the sulphate a hard crust. Both together will also form a solid incrustation, more or less hard in proportion as the one or the other of the salts predominates. This deposit, when allowed to accumulate, forms a hard scale which adheres very tenaciously to the iron and is troublesome to remove. There is, no doubt, much difficulty experienced by the owners of boilers in judging of the quality of the water they have to use, but it is always open to them to have a chemical analysis made; and this is often essential when there are two or more sources of supply in the same locality, as the water, although apparently obtained from the same primary source, may differ very greatly in its composition at two different points. There is an instance of this in a well which produced almost pure water, containing an alkali, but no lime. From this well a boiler was supplied for many years without any incrustation having been formed, the boiler being cleaned by simply brushing out. Within half a mile of this well another was sunk, but which yielded water containing so large a proportion of lime that in a few weeks a thick incrustation was formed within the boiler fed with it. Both wells were sunk through the London clay into the chalk. It is a fallacy to attempt to estimate water from its appearance; transparency does not always mean purity. A specimen of water of perfect apparent purity taken from a London pump, gave, on testing, 140 grains of different kinds of salts per gallon of water, whilst a sample taken from the Thames—considered bad enough—yielded at the most 20 grains of salts per gallon tested.

"Of the preventions and remedies which have been proposed from time to time, it may be said their name is legion; they form the subject of a goodly number of patents. Among the preventives are various methods of filtration and purification by chemical processes, whilst the remedies consist chiefly of a variety of compounds best known as 'boiler compositions.' Apart from the doctoring processes, are several simple and inexpensive remedies which have proved very effective in preventing incrustation. One of these consists in placing small logs of oak, with the bark on, in the boiler, which has the effect of reducing the carbonate of lime to a kind of sludge, which falls to the bottom and thus preserves the boiler perfectly clean. This plan has been pursued by one of the London water companies for many years with perfect success. Mahogany sawdust has been employed with advantage for the same purpose as the oak logs. It acts in two ways—first, mechanically, by offering so many small points on which the carbonate and sulphate of lime may be deposited, and secondly, by a peculiar action of the extractive matter in the wood. This applies more particularly to oak, especially when green, in which state it should be used. In North Wales the water used in boilers is orten perfectly green, and oak sawdust is administered in considerable quantities. Chloride of ammonium will convert the lime salts into soluble compounds, viz., sulphate and carbonate of ammonia, and chloride of calcium; but in practice its use has not been very successful, owing to the sal ammoniac and ammoniacal salts acting on the brass-work. Where the action of a cure is only partial, as is the case with some boiler fluids, the remedy is worse than the disease. For instance, in some boilers at Woolwich supplied with Thames water, a certain composition was used in the hope of preventing incrustation. It was found that the composition only acted upon the lighter portion of the sediment, leaving untouched the heavier and harder portion, which, though forming a much thinner deposit, was nevertheless impenetrable to the water, whilst, on leaving the lighter and the heavier ingredients undisturbed, they were found to form a porous substance through which the water could reach the plates.

"Prevention is at all times better than cure, and under ordinary circumstances, where the construction of the boiler does not insure immunity, the most practical plan for the prevention of incrustation is the adoption of an efficient mode of blowing-out. A more complete remedy, however, exists in the adoption of what is termed dry, or surface condensation. But the benefits to be derived from judicious blowing-out are not generally realised, or there would not be the irregularity there is in the use of the blow-out apparatus. To be effectual in its operation it should be used at regular intervals during the day, the best time being whenever the engine is not at work and the water therefore at rest. Under these conditions the sediment has an opportunity of settling, whereas at other times it will be held in suspension by the rising bubbles of *steam,* when blowing-out will be comparatively useless. But, however regularly the operation may be performed, it cannot be effectual if confined to one point only in the boiler, when there is a heavy sediment. But the action may be distributed throughout the whole length of the boiler by having a perforated pipe carried from end to end.

"A simple method of depriving water of its earthy carbonates was successfully adopted in a small high-pressure boiler. This was done by admitting a very small jet of cold water into the exhaust pipe of the engine, where, mingling with the waste steam, it condensed a portion of it. The steam, by raising the water to boiling heat, drove off the free carbonic acid, and the neutral carbonates were thrown down on the sides of the pipe, which was made large enough to allow it to accumulate. The water then ran down into a tank, whence it was pumped into the boiler at a temperature of about 200 deg. In addition to this, the partial condensation of the waste steam reduced the back pressure on the piston, and the result was a saving of half the fuel, the boiler remaining quite free from scale. But better than all these is the plan of using boilers properly constructed in the first instance, by which incrustation is reduced to a minimum, if not entirely prevented. By a properly constructed boiler is meant one so arranged that a proper circulation of the water is effected. In boilers thus designed such a thing as scaling is of very rare occurrence. In marine boilers incrustation was at one time a perplexing matter to deal with, as it was supposed to be impossible to prevent the boilers of a steamer from becoming salted up in some seas. But it has been ascertained that the saltness of different seas varies but little, and however salt the water may be, the boiler can be preserved from any injurious amount of incrustation by blowing-out as already noticed. This operation, to be effectual, should be performed very frequently, or a portion of the super-salted water may occasionally be allowed to escape. But, by proper blowing-out, a very slight scale, at the most, will ever be found. There is no excuse for the engineer who allows his boiler to become damaged from incrustation."

Thirdly, on the *preservation* of boilers. In this paper the writer returned to the subject of incrustation, showing that the best way to prevent it, and, in so preventing it, tending to ensure *the preservation* of the boiler was the adoption of the system of blowing-out. And in noticing the benefit of this he draws attention to the fact that the *fittings* of a boiler connected with the blowing-out apparatus are, as a rule, very generally uncared for. "Great carelessness," he says, "is frequently evinced with respect to blow-out taps and valves, and cases are not wanting in which a criminal recklessness has been displayed. The apparatus generally used consists of slides, mushroom valves, wing valves, and taps. With respect to sluices or slides, the experience is that they work freely, but they will not always close perfectly, so that it may, and in fact does, at times happen that they are accidentally left open. The safety of the boiler is thus imperilled, as the water is brought down very rapidly. It sometimes occurs, too, that they cannot be closed, owing to the sediment becoming lodged in the bottom of the slide or sluice boxes. The mushroom valve is readily opened and permits a free escape, but it is often found that particles of scale blown out with the water effectually prevent the reseating of the valve, which has frequently led to their disuse. The most satisfactory is the wing valve, which is found to work in an efficient and regular manner. The use of cast-iron taps is to be deprecated; they often corrode, and, sticking fast, are utterly useless. Those made of cast-iron in the shell and brass in the plug are liable to draw back in working. They often give trouble in consequence of the unequal expansion of the metals. They are generally difficult to close if opened when steam is up, which jeopardises the furnace crowns, so that where such taps are fitted their use is frequently limited to the occasional emptying of the boiler. The description of taps found to give the most satisfaction in general use are those made wholly of brass both in the plug and shell, and fitted with glands and packed. There is a greater safety in their use than in that of the common plug tap, in which the fastening often gets loose, and on opening the plug flies out, severe scalding being the result. Cast-iron taps having the plug and shell bushed with brass are found to work well, although it is a question whether, on the whole, they are more economical than those made of brass throughout. Long levers for opening and closing the taps should be avoided, as they strain them and often lead to fracture. The arrangement for carrying off the water too, is often very inefficient; a *proper waste pipe should* always be attached, otherwise the probability of a scalding will militate against the proper use of the apparatus, or when used will lead to the corrosion of the boiler plates by the saturation of the setting.

"Another ready method of preventing incrustation is by blowing out the scum from the surface of the water by means of a scum-pipe before it has an opportunity of settling. The system has long been used in marine boilers, and there is no reason why it should not be generally adopted in stationary boilers. The pipe about to be described is stated by Mr. Fletcher, chief engineer of the Manchester Boiler Association, to have been designed for the use of the members, and to be in use in many boilers with great success. In some instances boilers, after a month or six weeks' work, used to be coated with a heavy muddy deposit, whereas they are now perfectly clean. The description of pipe adopted is about three or four inches in diameter, having a wing cast on each side so as to form a trough throughout the entire length of the pipe. This pipe is carried within the boiler from one end to the other, being made in any convenient lengths for introduction at the man-hole. On the top it is perforated longitudinally with small holes, the aggregate area of the whole number of the holes being equal to that of the pipe itself. The top of the trough is placed a few inches below water level, so that the scum may flow over it, when, being guarded from disturbance by ebullition, it deposits in the still water above the trough the sedimentary particles held by it in mechanical combination. By means of a tap which communicates with the scum-pipe, and which is fixed to the front end plate of the boiler, the deposit may be blown out as often as necessary, which should be about every two hours during ebullition. The tap should be about two inches in diameter, made entirely of brass, fitted with a gland, and having a wrought-iron waste pipe attached. The waste pipes from the glass water gauges may be connected with it, being led directly under the dead plate, which makes a compact arrangement. The most convenient place to fix the scum-pipe is at the side of the boiler rather than in the centre, as in the latter position it is more easily fixed, and offers less obstruction to getting inside the boiler. The foregoing scum-pipe is simple in construction, and affords a large collecting area; it has another strong point in its favour, it is not the [illegible] of a patent, so can be used without fear of royalty being asked thereon. There are, however, other plans in operation which are subject to patent right. One of these consists of a series of vertical tubes, which are fixed in the centre of the boiler. Each tube terminates in a trumpet mouth, to which a vertical telescopic movement is given to allow for the changes of water level, the movement being effected by a copper-ball float, so that the mouth of the pipe is kept immediately below the surface of the water in close proximity to the scum. This, and other arrangements of a similar character, are found to answer satisfactorily.

"But incrustation is sometimes formed under peculiar circumstances, and cannot be entirely removed by the blowing-out apparatus alone. In general a small quantity of carbonate of soda introduced into the boiler is found to have a very wholesome effect, but soda should only be used in boilers provided with a scum-pipe, as otherwise the soda, combining with the grease in the boiler, produces foaming in the water, which leads to priming. We have previously stated our views with regard to 'boiler compounds,' and we find the general testimony to be against them. As a rule they are found to be expensive, some useless, and others injurious. It would, however, be unfair to close the question with such a general sweeping condemnation, when exceptions do here and there crop out. But these exceptions are very rare, and only become such by the compound being used in cases to which it is specially applicable, and not as an indiscriminate remedy for corrosion or incrustation. One instance of the efficacy of a boiler compound which has come under our notice is that of the boilers at the Phœnix Iron Works, Manchester, belonging to Messrs. Elce. The water used is drawn from the Ashton canal and is strongly acidulated, giving much trouble. After several months' use of a boiler compound (Wood and Hall's) it is stated that a very successful result ensued. One of the principal ingredients in this compound is a strong caustic alkali, which converts the acid in the water to a sulphate of soda, the lime, from which the acid has been liberated, falling as a powder to the bottom of the boiler to be blown out, or being carried off by the scum-pipe or other means. There are a few other compounds well spoken of, but in any case the utmost caution should be observed in their use. The adoption of surface condensers, although an expense at first, will nevertheless prove of incalculable benefit in the end, besides effecting a great saving in water rates and in fuel. But a step in advance of this is the apparatus M. Emile Martin substitutes for the surface condenser, which has been so recently noticed in our columns (Feb. 17, p. 100) as to render description here unnecessary. It suffices to say that M. Martin separates the salts held in solution in the feed water by the aid of superheated steam, the deposit of scale taking place in a chamber connected with the boiler instead of in the boiler itself. By this apparatus the surface condenser is in effect superseded."

21. *On the use of Soda in Boiler Incrustation.*—In last paragraph the reader will have noticed the reference made to the use of this substance. In a subsequent article in the same magazine (Mechanics', under date May 20th, 1865) the following remarks were given along with others—for which, however, we have unfortunately no space—in connection with the subject. "Of all the numerous chemical substances that have been brought into use against the calcareous incrustations of boilers, the common soda of commerce has been the most extensively employed. It enters into the composition of most of the patented boiler nostrums, and is probably almost always the most useful ingredient in them. It is one of the cheapest of chemicals; leaving no injurious action upon iron; being also perfectly harmless to the human system (unlike those highly poisonous substances, arseniate of soda and oxalate of potash, the former of which has been patented); and it has, finally, the peculiar merit of doing several services to the feed water at one and the same time. Not only does it decompose the sulphate of lime, and neutralise any free acid that might be present in the water, but it also serves to destroy any greasy matter possibly present, the injurious effects of which are scarcely to be doubted. The only precaution that need be taken in using carbonate of soda is to avoid having a large excess in the boiler, as it may then act injuriously upon the engine-packing.

"Although sulphate of lime is comparatively but little soluble—100 parts of water at 77 deg. Fahrenheit dissolving only 0·254 parts of sulphate of lime, whereas, of common salt, for instance, water dissolves more than one-third its weight—it must yet be practically considered as the only crust-forming substance, as its crystalline form and hardness induce the firm caking together of all the other *debris*, even when it is present in small quantity, there are practical proofs that no hard incrustation is formed when it is absent, except under very peculiar circumstances. It is present in sea water, and in most fresh waters, and begins to be deposited as soon as the water in the boiler has reached a certain degree of density, or, in high pressure engines, at a pressure of but two atmospheres, or 124 deg. Centigrade. Now, besides carbonate of soda, there are only two substances which can be practically employed for the decomposition of this injurious salt, viz., carbonate of potash and chloride of barium, but they are both much dearer. These facts are the plainest evidence of the value of carbonate of soda against boiler incrustations. Mr. L. E. Fletcher, the chief engineer to the Manchester Association for the Prevention of Steam Boiler Explosions, in his report for January 1863, says:—'The use of soda for the prevention of incrustation is found of considerable advantage and increasingly adopted.' He adds in conclusion that 'there are but few cases of incrustation which the use of soda, combined with regular blowing out from the surface of the water, will not check.' It is not easy to determine the amount of soda required to exactly decompose all the sulphate of lime in the feed-water. Mr. J. R. Napier, in a paper read before the Glasgow Philosophical Society in 1858, states that he analyses the feed water to ascertain the amount of sulphate of lime per gallon, and then calculates the amount of carbonate of soda requisite to exactly neutralise the sulphate of lime in the water taken per day. He keeps it dissolved in a small iron tank placed above, and communicating with, the boiler by means of a syphon or tap so arranged as to run the soda liquor in gradually whilst working, so that there is never an excess of carbonate of soda present. It is not, however, always easy to have an exact quantitative estimation of the amount of sulphate of lime in the water. The following plan, recommended by Mr. Spence before the Manchester Literary and Philosophical Society, may therefore be more acceptable to the practical man. A small vessel, capable of containing about two gallons of water, is placed on the suction portion of the water-pipe by which the boiler is supplied, and a pipe of half an inch in diameter communicates from the water-pipe to this vessel. Every day the boiler man puts into this vessel from one to one and a half pounds of soda ash. In feeding the boiler the fireman turns the small cock, when in three or four minutes all the solution is taken up and passed through the feed-pump. This is repeated daily, and the consequence is that not the slightest incrustation is formed Mr. Fletcher, in the report previously alluded to, also says, 'The soda is better introduced in small regular doses than in large infrequent doses. In many cases there might be fitted to the suction-pipe of the feed-pump a funnel mouth, by means of which the requisite charge could be introduced into the boiler without difficulty; its rate of ingress being regulated by a tap between it and the suction-pipe. In many cases a separate feed-pump has been adopted, fitted with a small cistern containing a day's supply, and this arrangement has been found to work most satisfactorily.'

"The next purpose for which carbonate of soda is very useful is for neutralising any free acid which might be present in the feed-water, and which would cause a very destructive corrosion of the boiler, not only by simply attacking the iron, but possibly also by inducing a voltaic action between the non-homogeneous parts of the boiler plates, upon the principle lately pointed out by Mr. Paget.

"Perhaps the only chemicals (besides carbonate of soda) in common use, against boiler incrustations, which have at least the merit of being certainly perfectly innoxious to the iron, are—chloride of barium, which decomposes the sulphate of lime, and is employed on the continent, but is at present too expensive here in England for practical use; and lime (Dr. Clarke's lime process), which is employed at several waterworks, but can only be used for purifying the feed-water from carbonate of lime *previous* to its introduction into the boiler.

"The average price of commercial carbonate of soda is about eightpence per pound; white soda ash is but little inferior for use in steam boilers, although it contains more of the usual impurities, such as sulphate and chloride of sodium; the price is sixpence per pound. Larger quantities would, of course, be cheaper. In conclusion, it may perhaps be expedient to remark *that, injurious* as an incrustation really is, it sometimes appears been pursued by one of the London water companies for many years with perfect success. Mahogany sawdust has been employed with advantage for the same purpose as the oak logs. It acts in two ways—first, mechanically, by offering so many small points on which the carbonate and sulphate of lime may be deposited, and secondly, by a peculiar action of the extractive matter in the wood. This applies more particularly to oak, especially when green, in which state it should be used. In North Wales the water used in boilers is orten perfectly green, and oak sawdust is administered in considerable quantities. Chloride of ammonium will convert the lime salts into soluble compounds, viz., sulphate and carbonate of ammonia, and chloride of calcium; but in practice its use has not been very successful, owing to the sal ammoniac and ammoniacal salts acting on the brass-work. Where the action of a cure is only partial, as is the case with some boiler fluids, the remedy is worse than the disease. For instance, in some boilers at Woolwich supplied with Thames water, a certain composition was used in the hope of preventing incrustation. It was found that the composition only acted upon the lighter portion of the sediment, leaving untouched the heavier and harder portion, which, though forming a much thinner deposit, was nevertheless impenetrable to the water, whilst, on leaving the lighter and the heavier ingredients undisturbed, they were found to form a porous substance through which the water could reach the plates.

"Prevention is at all times better than cure, and under ordinary circumstances, where the construction of the boiler does not insure immunity, the most practical plan for the prevention of incrustation is the adoption of an efficient mode of blowing-out. A more complete remedy, however, exists in the adoption of what is termed dry, or surface condensation. But the benefits to be derived from judicious blowing-out are not generally realised, or there would not be the irregularity there is in the use of the blow-out apparatus. To be effectual in its operation it should be used at regular intervals during the day, the best time being whenever the engine is not at work and the water therefore at rest. Under these conditions the sediment has an opportunity of settling, whereas at other times it will be held in suspension by the rising bubbles of *steam*, when blowing-out will be com-is not carbonate of lime, for that is insoluble, and the assuming of that form causes all the difficulty. We must, therefore, look to some other combination, for every new combination of chemical atoms has different results, and these atoms, according to late authority, unite in definite proportions, and not otherwise; hence, one atom of lime united with one atom of carbonic acid will form carbonate of lime (insoluble). If one atom of lime unite with two atoms of carbonic acid, it will be super-carbonate of lime, a substance that is soluble, and which, we contend, is the true condition of lime in hard water.

"Limestone is carbonate of lime. By being burned in a lime-kiln is is deprived of its carbon, and its water of crystallisation, and becomes quick-lime. It then seizes upon a certain quantity of water or carbonic acid wherever it may come in contact with them, or either of them. Now, take a small quantity of quick-lime, either dissolved in water or otherwise, and put it in common hard water, and it will immediately seize upon the surplus carbon of the supercarbonate of lime, and reduce all the lime in the water to carbonate of lime, which will be insoluble, and will immediately fall to the bottom of the vessel, leaving the water as pure as water can be; hence the impossibility of its coating a boiler. It only requires two tanks or tubs for water, that one may be settled while the other is filled, or, if the engine be supplied from a well, and worked only in the daytime, the lime may be put in the well itself of an evening, and it will be settled before morning. The quantity of lime proper to be used can be tested by litmus paper. If there be a small surplus quantity of lime it cannot injure the boiler.

"To remove incrustations in a steam boiler, I have chosen still-slop, an article not heretofore used. It costs but little, and contains a large quantity of vegetable acid, which is not severe on iron. I do not claim the discovery of any new chemical principle. I have long been aware that vegetable acids would decompose carbonate of lime. I am also aware that quick-lime has been used to break what is called hard water; but I do claim the right to use or employ known materials for a purpose which is new and useful, when such appliance has never been authorised, patented, known, or published. What, therefore, I *desire to secure* by letters patent is the use of still-slop to preblowing-out. And in noticing the benefit of this he draws attention to the fact that the *fittings* of a boiler connected with the blowing-out apparatus are, as a rule, very generally uncared for. "Great carelessness," he says, "is frequently evinced with respect to blow-out taps and valves, and cases are not wanting in which a criminal recklessness has been displayed. The apparatus generally used consists of slides, mushroom valves, wing valves, and taps. With respect to sluices or slides, the experience is that they work freely, but they will not always close perfectly, so that it may, and in fact does, at times happen that they are accidentally left open. The safety of the boiler is thus imperilled, as the water is brought down very rapidly. It sometimes occurs, too, that they cannot be closed, owing to the sediment becoming lodged in the bottom of the slide or sluice boxes. The mushroom valve is readily opened and permits a free escape, but it is often found that particles of scale blown out with the water effectually prevent the reseating of the valve, which has frequently led to their disuse. The most satisfactory is the wing valve, which is found to work in an efficient and regular manner. The use of cast-iron taps is to be deprecated; they often corrode, and, sticking fast, are utterly useless. Those made of cast-iron in the shell and brass in the plug are liable to draw back in working. They often give trouble in consequence of the unequal expansion of the metals. They are generally difficult to close if opened when steam is up, which jeopardises the furnace crowns, so that where such taps are fitted their use is frequently limited to the occasional emptying of the boiler. The description of taps found to give the most satisfaction in general use are those made wholly of brass both in the plug and shell, and fitted with glands and packed. There is a greater safety in their use than in that of the common plug tap, in which the fastening often gets loose, and on opening the plug flies out, severe scalding being the result. Cast-iron taps having the plug and shell bushed with brass are found to work well, although it is a question whether, on the whole, they are more economical than those made of brass throughout. Long levers for opening and closing the taps should be avoided, as they strain them and often lead to fracture. The arrangement for carrying off the water too, is often very inefficient; a proper waste pipe should always be attached, otherwise the probability of a scalding will militate against the proper use of the apparatus, or when used will lead to the corrosion of the boiler plates by the saturation of the setting.

"Another ready method of preventing incrustation is by blowing out the scum from the surface of the water by means of a scum-pipe before it has an opportunity of settling. The system has long been used in marine boilers, and there is no reason why it should not be generally adopted in stationary boilers. The pipe about to be described is stated by Mr. Fletcher, chief engineer of the Manchester Boiler Association, to have been designed for the use of the members, and to be in use in many boilers with great success. In some instances boilers, after a month or six weeks' work, used to be coated with a heavy muddy deposit, whereas they are now perfectly clean. The description of pipe adopted is about three or four inches in diameter, having a wing cast on each side so as to form a trough throughout the entire length of the pipe. This pipe is carried within the boiler from one end to the other, being made in any convenient lengths for introduction at the man-hole. On the top it is perforated longitudinally with small holes, the aggregate area of the whole number of the holes being equal to that of the pipe itself. The top of the trough is placed a few inches below water level, so that the scum may flow over it, when, being guarded from disturbance by ebullition, it deposits in the still water above the trough the sedimentary particles held by it in mechanical combination. By means of a tap which communicates with the scum-pipe, and which is fixed to the front end plate of the boiler, the deposit may be blown out as often as necessary, which should be about every two hours during ebullition. The tap should be about two inches in diameter, made entirely of brass, fitted with a gland, and having a wrought-iron waste pipe attached. The waste pipes from the glass water gauges may be connected with it, being led directly under the dead plate, which makes a compact arrangement. The most convenient place to fix the scum-pipe is at the side of the hboiler rather than in the centre, as in the latter position it is 'rre easily fixed, and offers less obstruction to getting inside the writer". The foregoing scum-pipe is simple in construction, and best way large collecting area; it has another strong point in its the preservis not the subject of a patent, so can be used without fear of royalty being asked thereon. There are, however, other plans in operation which are subject to patent right. One of these consists of a series of vertical tubes, which are fixed in the centre of the boiler. Each tube terminates in a trumpet mouth, to which a vertical telescopic movement is given to allow for the changes of water level, the movement being effected by a copper-ball float, so that the mouth of the pipe is kept immediately below the surface of the water in close proximity to the scum. This, and other arrangements of a similar character, are found to answer satisfactorily.

"But incrustation is sometimes formed under peculiar circumstances, and cannot be entirely removed by the blowing-out apparatus alone. In general a small quantity of carbonate of soda introduced into the boiler is found to have a very wholesome effect, but soda should only be used in boilers provided with a scum-pipe, as otherwise the soda, combining with the grease in the boiler, produces foaming in the water, which leads to priming. We have previously stated our views with regard to 'boiler compounds,' and we find the general testimony to be against them. As a rule they are found to be expensive, some useless, and others injurious. It would, however, be unfair to close the question with such a general sweeping condemnation, when exceptions do here and there crop out. But these exceptions are very rare, and only become such by the compound being used in cases to which it is specially applicable, and not as an indiscriminate remedy for corrosion or incrustation. One instance of the efficacy of a boiler compound which has come under our notice is that of the boilers at the Phœnix Iron Works, Manchester, belonging to Messrs. Elce. The water used is drawn from the Ashton canal and is strongly acidulated, giving much trouble. After several months' use of a boiler compound (Wood and Hall's) it is stated that a very successful result ensued. One of the principal ingredients in this compound is a strong caustic alkali, which converts the acid in the water to a sulphate of soda, the lime, from which the acid has been liberated, falling as a powder to the bottom of the boiler to be blown out, or being carried off by the scum-pipe or other means. There are a few other compounds well spoken of, but in any case the utmost caution should be observed in their use. The adoption of surface condensers, although an expense at first, will nevertheless prove of incalculable benefit in the end, besides effecting a great saving in water rates and in fuel. But a step in advance of this is the apparatus M. Emile Martin substitutes for the surface condenser, which has been so recently noticed in our columns (Feb. 17, p. 100) as to render description here unnecessary. It suffices to say that M. Martin separates the salts held in solution in the feed water by the aid of superheated steam, the deposit of scale taking place in a chamber connected with the boiler instead of in the boiler itself. By this apparatus the surface condenser is in effect superseded."

21. *On the use of Soda in Boiler Incrustation.*—In last paragraph the reader will have noticed the reference made to the use of this substance. In a subsequent article in the same magazine (Mechanics', under date May 20th, 1865) the following remarks were given along with others—for which, however, we have unfortunately no space—in connection with the subject. "Of all the numerous chemical substances that have been brought into use against the calcareous incrustations of boilers, the common soda of commerce has been the most extensively employed. It enters into the composition of most of the patented boiler nostrums, and is probably almost always the most useful ingredient in them. It is one of the cheapest of chemicals; leaving no injurious action upon iron; being also perfectly harmless to the human system (unlike those highly poisonous substances, arseniate of soda and oxalate of potash, the former of which has been patented); and it has, finally, the peculiar merit of doing several services to the feed water at one and the same time. Not only does it decompose the sulphate of lime, and neutralise any free acid that might be present in the water, but it also serves to destroy any greasy matter possibly present, the injurious effects of which are scarcely to be doubted. The only precaution that need be taken in using carbonate of soda is to avoid having a large excess in the boiler, as it may then act injuriously upon the engine-packing.

"Although sulphate of lime is comparatively but little soluble—100 parts of water at 77 deg. Fahrenheit dissolving only 0·254 parts of sulphate of lime, whereas, of common salt, for instance, water dissolves more than one-third its weight—it must yet be practically considered as the only crust-forming substance, as its crystalline form and hardness induce the firm caking together of all the other *debris*, even when it is present in small quantity, there are practical proofs that no hard incrustation is formed when it is absent, except under very peculiar circumstances. It is present in sea water, and in most fresh waters, and begins to be deposited as soon as the water in the boiler has reached a certain degree of density, or, in high pressure engines, at a pressure of but two atmospheres, or 124 deg. Centigrade. Now, besides carbonate of soda, there are only two substances which can be practically employed for the decomposition of this injurious salt, viz., carbonate of potash and chloride of barium, but they are both much dearer. These facts are the plainest evidence of the value of carbonate of soda against boiler incrustations. Mr. L. E. Fletcher, the chief engineer to the Manchester Association for the Prevention of Steam Boiler Explosions, in his report for January 1863, says:—'The use of soda for the prevention of incrustation is found of considerable advantage and increasingly adopted.' He adds in conclusion that 'there are but few cases of incrustation which the use of soda, combined with regular blowing out from the surface of the water, will not check.' It is not easy to determine the amount of soda required to exactly decompose all the sulphate of lime in the feed-water. Mr. J. R. Napier, in a paper read before the Glasgow Philosophical Society in 1858, states that he analyses the feed water to ascertain the amount of sulphate of lime per gallon, and then calculates the amount of carbonate of soda requisite to exactly neutralise the sulphate of lime in the water taken per day. He keeps it dissolved in a small iron tank placed above, and communicating with, the boiler by means of a syphon or tap so arranged as to run the soda liquor in gradually whilst working, so that there is never an excess of carbonate of soda present. It is not, however, always easy to have an exact quantitative estimation of the amount of sulphate of lime in the water. The following plan, recommended by Mr. Spence before the Manchester Literary and Philosophical Society, may therefore be more acceptable to the practical man. A small vessel, capable of containing about two gallons of water, is placed on the suction portion of the water-pipe by which the boiler is supplied, and a pipe of half an inch in diameter communicates from the water-pipe to this vessel. Every day the boiler man puts into this vessel from one to one and a half pounds of soda ash. In feeding the boiler the fireman turns the small cock, when in three or four minutes all the solution is taken up and passed through the feed-pump. This is repeated daily, and the consequence is that not the slightest incrustation is formed Mr. Fletcher, in the report previously alluded to, also says, 'The soda is better introduced in small regular doses than in large infrequent doses. In many cases there might be fitted to the suction-pipe of the feed-pump a funnel mouth, by means of which the requisite charge could be introduced into the boiler without difficulty; its rate of ingress being regulated by a tap between it and the suction-pipe. In many cases a separate feed-pump has been adopted, fitted with a small cistern containing a day's supply, and this arrangement has been found to work most satisfactorily.'

"The next purpose for which carbonate of soda is very useful is for neutralising any free acid which might be present in the feed-water, and which would cause a very destructive corrosion of the boiler, not only by simply attacking the iron, but possibly also by inducing a voltaic action between the non-homogeneous parts of the boiler plates, upon the principle lately pointed out by Mr. Paget.

"Perhaps the only chemicals (besides carbonate of soda) in common use, against boiler incrustations, which have at least the merit of being certainly perfectly innoxious to the iron, are—chloride of barium, which decomposes the sulphate of lime, and is employed on the continent, but is at present too expensive here in England for practical use; and lime (Dr. Clarke's lime process), which is employed at several waterworks, but can only be used for purifying the feed-water from carbonate of lime *previous* to its introduction into the boiler.

"The average price of commercial carbonate of soda is about eightpence per pound; white soda ash is but little inferior for use in steam boilers, although it contains more of the usual impurities, such as sulphate and chloride of sodium; the price is sixpence per pound. Larger quantities would, of course, be cheaper. In conclusion, it may perhaps be expedient to remark that, injurious as an incrustation really is, it sometimes appears to benefit the internal surface of the boiler by partly preserving it from direct contact with the water, and the consequent rusting; whereas a clean and, consequently, unprotected boiler-plate, naturally succumbs more or less to the continual action of the water, and gets to a certain degree corroded internally. Some persons have, in consequence, unreasonably thrown the blame on the soda. It is, therefore, necessary to point out that this slight oxidation is most probably always nothing but the inevitable effects of wear and tear, and cannot be compared with the loss of from 20 to 70 per cent. of heat, the red hot and burnt plates, and the hundred and one other injuries and losses incurred by incrustations."

22. *American Plan for preventing Incrustation in Boilers.*— An American gentleman of the name of Mr. Davis Embree, of Dayton, Ohio, has presented to the Patent Commissioners of this country his Specification, with a request that "it might be published in the usual course of business." The following is the Specification referred to. "The groundwork of my invention, or rather application, I conceive to be founded on sound chemical principles. That lime is the basis of all incrustation in steam boilers. That it is generally found to be carbonate of lime or limestone. That it assumes the form of crystals. That it is insoluble in water. That particles of the same kind, in the formation of crystals, unite with each other, adding to the mass first formed or fixed. Incrustation of boilers may be dissolved by an acid which has stronger affinity to lime than carbonic acid has; the lime and such acid will unite, generally forming a compound that is soluble, and cannot coat a boiler, while the carbon passes off in form of carbonic acid gas. Incrustation can also be removed by an alkali that has a stronger affinity for carbonic acid than lime has; such alkali uniting with the carbonic acid leaves the lime in a pure state, which is soluble in a sufficient quantity of water, and cannot coat a boiler; the compound of such alkali with carbon will also generally be found soluble. To prevent incrustation in steam boilers, one other mode may be resorted to,—that of thoroughly boiling the water before it enters the steam boilers. These are the only means known to accomplish the object desired.

"There are but few persons aware of the exact condition in which lime is held in solution in what is called hard water. It is not carbonate of lime, for that is insoluble, and the assuming of that form causes all the difficulty. We must, therefore, look to some other combination, for every new combination of chemical atoms has different results, and these atoms, according to late authority, unite in definite proportions, and not otherwise; hence, one atom of lime united with one atom of carbonic acid will form carbonate of lime (insoluble). If one atom of lime unite with two atoms of carbonic acid, it will be super-carbonate of lime, a substance that is soluble, and which, we contend, is the true condition of lime in hard water.

"Limestone is carbonate of lime. By being burned in a lime-kiln is is deprived of its carbon, and its water of crystallisation, and becomes quick-lime. It then seizes upon a certain quantity of water or carbonic acid wherever it may come in contact with them, or either of them. Now, take a small quantity of quick-lime, either dissolved in water or otherwise, and put it in common hard water, and it will immediately seize upon the surplus carbon of the supercarbonate of lime, and reduce all the lime in the water to carbonate of lime, which will be insoluble, and will immediately fall to the bottom of the vessel, leaving the water as pure as water can be; hence the impossibility of its coating a boiler. It only requires two tanks or tubs for water, that one may be settled while the other is filled, or, if the engine be supplied from a well, and worked only in the daytime, the lime may be put in the well itself of an evening, and it will be settled before morning. The quantity of lime proper to be used can be tested by litmus paper. If there be a small surplus quantity of lime it cannot injure the boiler.

"To remove incrustations in a steam boiler, I have chosen still-slop, an article not heretofore used. It costs but little, and contains a large quantity of vegetable acid, which is not severe on iron. I do not claim the discovery of any new chemical principle. I have long been aware that vegetable acids would decompose carbonate of lime. I am also aware that quick-lime has been used to break what is called hard water; but I do claim the right to use or employ known materials for a purpose which is new and useful, when such appliance has never been authorised, patented, known, or published. What, therefore, I sire to secure by letters patent is the use of still-slop to prevent or remove incrustation by lime in steam boilers, and the use of quick-lime in the manner herein substantially set forth to prevent such incrustation."

23. *Novel Plan to prevent Incrustation in Boilers.*—The following letter has been addressed to the editor of a London Magazine:—"Sir,—I do not know a subject of greater interest to this country than the article on the Incrustation of Steam Boilers, so ably given in your last week's magazine. The fact is, steam is becoming of such paramount importance in every branch of industry that a simple efficacious plan for keeping boilers clean would be invaluable.

"Like every engineer connected with mines, I have had my difficulties with dirty water, and can feel for others in the same trouble. What I found best was the trays inside and blowing off a little often when the pressure was well up, and cleaning out every fortnight. This is a standing rule at most mines.

"Some time ago I had a thirty-horse engine to fix at a large mill in London, and certainly the water in the well was the worst I ever saw. I advised the parties to make arrangements with the water company, if possible; however, they could not come to terms, and so I was compelled to do something to get over the difficulty. It struck me at the time that, if I could boil the water sufficiently before pumping it into the boiler, it would fix a great deal of the solid matter. I accordingly had a tank made, 6 ft. long, 2 ft. deep, and 2 ft. broad, watertight, with a manhole on the top; the water inside was supplied from a cistern with a ball-tap, so as to keep the water 9 in. from the top; the exhaust steam from the engine played right on the top of the water and kept it boiling all day; two pipes conveyed the steam up through the roof. The effect was this, every week there was a slab of stone formed on each side of the tank, one inch and a half thick, which made it very difficult to break and get out at the man-hole, but with very little blowing off it saved the boiler. All I can say is that it is the best and simplest plan that I know, and one every engineer can adopt at a small expense. I may just mention that the water was so foul with the finest sand that no strainer would keep it from coming through the pump.

"J. W."

"MARCH 7, 1865.

SECTION FOURTH.

24. *Miscellaneous Notes on Boilers — Explosions, &c., &c. —Carelessness in Boiler Management.* — In an article on "Official Boiler Explosions" the Engineer, under date January 20, 1865, referring pointedly to a serious accident, involving the loss both of life and property, which resulted from the testing of a locomotive boiler in the repairing shed at the Great Northern Railway works at Peterborough, in which the test was "putting it under the pressure of 125 lb. steam—the usual pressure employed on such occasions being 130 lb."—thus remarks: "But the idea of trying this boiler with steam! Regarding only the eventual safety of the passengers, it is clear that, in common prudence, such a test must be necessarily kept very low, especially as it is the common opinion with engineers that, pressure for pressure, steam strains a boiler more than water.

"Now, we should like to know of what earthly use is all the talking or writing in the world against such recklessness as this —a recklessness equal to carrying out an operation, which consists in exploding a boiler in the repairing shed, to see whether it will not burst when put on the line. Of what use are all the newspaper writing, all the juries, all the Government inspectors, in the world, if these things can be carried on in the broad light of day? We shall again have the usual elaborate coroner's inquiry, the usual Government inspector's report, and the usual number of newspaper articles—and all again to no purpose. In fact, this case, however flagrant in reality, will be forgotten much sooner than any other incident of railway slaughter, as the people maimed are not travellers, but servants of the company. The Compensation Act does not apply here; even if it did, these working men could not carry forward a costly suit. As to the relatives of those killed outright, the company is probably quite safe against actions for damages by them. English law is, in many respects, so complicated—legal decisions depend from so many threads—that it is difficult to pronounce with certainty upon any question of this kind—especially when scientific technicalities add their complication to purely legal points. It is to be supposed that members of Parliament would not try to introduce a bill intended to correct an abuse without a legal basis of some soundness; and the bill attempted to be carried last session, by Mr. Ferrand and Colonel Edwards, 'for Compensating the Families of Persons killed by Boiler Explosions,' was to fill up what certainly appears to be a leak in the present law. It would seem that though a person merely injured by a boiler explosion through neglect can at present recover damages against the proprietor, the relatives of a person who is killed outright cannot do so, 'although the death shall have been caused under such circumstances as amount in law to felony.' According to this, a boiler explosion in England is the less likely to damage the owner's pockets when it kills the victims at once outright.

"The explosion at Messrs. Sharp, Stewart, and Co.'s was, at least to some extent, excusable. In the first place, an explosion of a new boiler through a defective plate is of very uncommon occurrence; there is some guarantee that a new boiler is safe, as both sides of the plates would have been quite recently visible. No unexpected deteriorating influence could have been at work here. Secondly, even as recently as six or seven years ago, boiler explosions were generally ascribed to mysterious and unaccountable agencies, just as the French still make a distinction between ordinary explosions and *explosions 'fulminantes.'* Thirdly, the manager of the works showed his confidence in the boiler by being present at its testing by steam.

"It is probable that, by the time a locomotive superintendent is blown up by one of his own boilers, we shall have a general reform in this direction. Not one of these excuses is tenable here, and the whole affair must be ascribed to parsimonious or careless management. The great majority of these explosions are due to the failure of one or more of the plates of the barrel through grooving, and as long as the greater number of the tubes are not drawn, these furrows cannot be seen. Now one of these tubes costs from 25s. to 27s., and some engines have more than 300 tubes. When drawn, the same tube cannot be replaced, and the drawing also injures the tube-plates, which would often require reboring; so that there is certainly some difficulty in obtaining both economy and safety. In one word, the tubes last longer than the plates—or, rather, the plates which had been sound when a boiler was re-tubed, become dangerous in the interval between a fresh re-tubing. The only remedies are to be found in the adoption of welded or of butt longitudinal joints, or of stiffening rings at the transverse joints, or both. In this way the deterioration of the plates through grooving could not easily outstrip the wear of the brass tubes. If our superintendents, instead of scheming out patents, profitable to themselves but very dear in experimental determination to the companies, were to give their attention to a safer boiler, the question would be soon settled; but there can be no safety without periodical internal examination, and this cannot be obtained without drawing at least a portion of the tubes. Whether locomotive boilers could be so built as to permit the withdrawal of the tubes, by making turned and bolted joints at the smoke-box and fire-box, is a question well worth trying. The plan has been successfully carried out in England for portable engine boilers, and we have seen tubular boilers on this plan on the Continent, up to 30-horse power. But even with all these precautions uncertainty will always exist as long as boilers are not periodically tested, and, at the same time, examined internally.

"As to testing boilers on the Great Northern plan, no words are strong enough to express our opinion on the matter. Gunmakers might just as well prove their barrels without carefully enclosing them in a bullet-proof building, or chain testers might just as well stand by to be cut in two by the back lash of a breaking cable. We only hope that the Great Northern Company will be treated as they deserve in the matter of compensations to their injured servants or their survivors."

25. *Mysterious Boiler Explosions.*—Under the above title the "Scientific American" has the following. "That steam boilers are long-suffering and endure neglect and abuse without destroying the authors of them, is amply proved by hosts of occurrences similar to those related below. By late English mails we learn that a boiler in Birmingham, England, which was worked from a puddling furnace, became so hot that, through want of water, the plates exposed simply bulged out and tore away like a sheet of pasteboard. No other results followed, and the damage ended with the rupture. In another case mud accumulated in a cylinder boiler which caused the plates covered by it to burn out, when *the pressure within* merely rent the metal, and extinguished the

fire; no sooner was the plate replaced by a new one than a similar accident occurred from the same cause. Another injury was caused by reliance upon a float for ascertaining the height of water, although there were gage cocks in addition; the float became jammed, and the water was evaporated until twelve feet of the boiler became red-hot, resulting in great expense for repairs.

"If these boilers had been blown to atoms, if the surrounding buildings had been reduced to rubbish, if hundreds of human beings had been wounded and maimed for life, we should have the theory-tinkers on the stand again, and 'ozone' would have been heard from. We should have been told that some mysterious agent, some unknown but tremendous force had been generated by the decomposition of the water, and was the sole cause. Saturated steam discharged from a sound boiler into the superheated atmosphere of the exploded boiler, might have been the cause. In short, there would have been repeated the same farce which is re-enacted whenever a casualty of like nature occurs.

"In the cases above cited the boilers themselves knew more than the seekers after mystery do. The one burnt out gave way from a palpable cause, and the same neglect transpiring shortly after, it failed again, showing that it was simply impossible to exist under such a combination of causes. It is so with all boiler explosions. Nine out of every ten can be traced to actual deterioration from long service or misuse, and it is a disgrace to the engineering profession that they should countenance efforts made to shroud them in mystery. The result of such verdicts is simply to invite neglect, for if the engine-tender is given to understand that a boiler will explode by causes beyond his control, he becomes a sort of predestinarian, and trusts to luck, when he ought to be the personification of vigilance. All the mystery is the mystery of carelessness which might be prevented."

26. *On the Cause of the Violence occasionally attending the Explosion of Steam Boilers.*—The following is an abstract of a paper under the above title in the "English Mechanic," under dates September 29th and October 6th, 1865. "Few questions of practical science are surrounded with greater mystery than the cause of the violence with which boiler explosions are sometimes accompanied. If a *comparative* degree of violence was at all *times associated with the explosion* of boilers, no doubt the cause

of the explosion itself could be ascertained. This, however, does not happen to be the case. By far the greater number of boilers are destroyed quietly, and without any greater manifestation of violence than if they were simply burst open by cold hydraulic pressure. This seeming paradox of explosions occurring under the two opposite conditions has involved the whole question of boiler explosion in uncertainty. It is a singular fact that the more dangerous and formidable explosions have been known to have taken place in boilers while at their ordinary working pressures, whereas one would generally be led to consider that, except in cases of undue pressure, or some inherent defect in the construction of the boiler, no explosion could come to pass. The majority of ordinary boiler explosions which occur unattended by any great amount of percussive force or detonation are induced, no doubt, owing to some defect which is unobserved during the construction of the boiler, or which becomes developed while the boiler is in process of working. It is surprising, however, to reflect that at least seven out of every ten boiler explosions which take place are put down to some entirely metaphysical and unexplained cause. Leakage is, of course, a very frequent forerunner of these catastrophes; but the forms under which leakage itself takes place are very numerous. Although few have been investigated with so satisfactory a result as could be wished, they are sufficiently marked to lead to the conclusion that their causes are very different. Vibration of the boiler in its bed, by causing some change in the molecular arrangement of certain parts of the boiler, may often lead to openings along the rivet seams, or in the plate itself, which afterwards become enlarged to full and developed leakages. When the water once finds a flow through the narrowest channel, it begins a scour upon the sides of the opening, tending to widen and increase the flow, and when the air is reached a combination sets in between the metal, and the oxygen contained in the water forming an oxide which is continually washed away by the force of the escaping water.

"The orifice then becomes widened by successive corrosions of the surfaces, while a steady oxidation sets in on all the surrounding parts. The same class of phenomena are also more or less associated with steam leakages occurring above the water line, *only that in this* case the growth of the leakage would be accelerated, as the abrasion of the escaping steam would operate upon the surfaces of the metal with more force than a leakage of water. This does not take place at first. Owing to the comparative freedom of steam from oxygen, very little decomposition of the surface of the metal would take place unless in the case of a leakage of long duration, as the hydrogen of the steam absorbs the oxygen from the air as soon as it meets with it in the course and direction of its escape. When condensation sets in round the leakage, oxidation commences, and the leakage is consequently rapidly extended. Probably in boiler engineering the various forms of leakage, and more especially those which result from vibration, do not meet with so much attention as they deserve. The familiar noise produced by a kettle may be heard upon a much more extensive scale in the case of a good-sized boiler in which the steam is being got up. In the one case the waves of vibration succeed each other so rapidly that, like the revolution of the prismatic colours on a disc, although they may not be in every respect the same as to duration and force, but a single impression is conveyed, being that of a uniform and prolonged sound. In the case of the boiler these vibrations assume the character of trilling concussions, each of which is perfectly distinguishable from those that precede or follow it, and very frequently these minute and innumerable shocks effect a serious modification in the material of which the boiler is formed.

"There is besides a constant circulation, as is commonly known, of the water in all boilers, tending to produce a great amount of vibration. This operates in oblong boilers, causing a current in the direction of their length from the front end to the back, and in other classes of boilers in a direction, of course, varying with their form. The velocity and force of this current differ with the quantity of water contained in the boiler and the intensity of the heat used to effect its conversion into steam.

"This is a serious and frequent cause of boiler destruction, for it must be remembered that when a certain heat is attained both in the steam and in the furnace, and corresponding conditions are established between the heat of the boiler itself and the atmosphere that surrounds it, a sort of communication is established between the *internal and external* atmospheres, and it is owing *to the want of a fuller knowledge* of the phenomena which transpire at this crisis, probably that many disastrous cases of boiler explosion may be fairly attributed. In boiler ruptures, caused simply by the expansive force of steam, it would seem as if in some cases gases of which steam is composed possess a force of adhesion, or combine with such strength after they have attained a certain degree of elasticity, that they do not operate in an inferior direction, but accumulating their force beyond this pitch they wait until they encounter some more formidable obstacle, and in a moment everything is hurled on to destruction by the fearful violence with which they become disengaged. The proximate cause of boiler explosion is yet involved in great obscurity. It was considered by Dobereiner, that chemical combinations and decombinations could be effected through the medium of the closest textures of iron, or other bodies, by simple capillarity, but the results attending the operation of caloric, light, and acidity are such that human ingenuity can scarcely hope to arrest them, however successfully such results may be provided against. The atmosphere where it comes in contact with the external surfaces of a boiler plays a much more important part than may be held generally to be the case. A boiler well heated and producing a good steam may be compared to a cylindrical body trying to hold all its parts together between two equally balanced forces which tend to separate them, by pressures acting in contrary directions. Whatever may be the subtle nature of the phenomena by the operation of which water becomes converted into steam, it is clear that a reciprocal change is continually going on between the atmospheres inside and outside the boiler. Besides its effective work in giving motion to the piston of an engine, steam operates very powerfully in another direction. The entire movements of an engine are due to the momentary diversion of steam force, from the more natural way in which it would seek to expand or set itself free. This it is always attempting to do except at the intervals when its force relaxes under a momentary but abnormal liberation into the cylinder. The true direction of steam is away from work. It has been found by recent experiment, that there is no class of metal so compact or homogeneous as to be altogether free from percolation, or the molecular structure of which would separate it from those that are known to be porous. Carburetted hydrogen passing through an ordinary iron gas pipe, although having a force of direction given to it, may be adduced as an illustration. Before the gas reaches the extremity of the tube not only will the hydrogen have exuded between the molecules of the tube, but other and entirely different gases will have entered and assumed its place. Thus, unless there is always a strong flowing current of gas, an explosion in exposed gas mains would be always imminent when a flame was brought near any opening made in them during the time of their being tapped, or bored for connections. When the current of gas flowing through them is strong the danger is diminished.

"It has been stated by some writers on boiler engineering that a continual change of pressure is taking place in the boiler, owing to the variation of the load put upon the engine, and that very little difference arises regarding the working of the boiler itself when once the steam is fairly up.

"Morosi was of opinion that on the stoppage of the piston at each end of its stroke, the whole force of the steam was so violently arrested as to cause it to strike back suddenly into the boiler, and burst it open. Now, it is obvious that wherever a force operates upon a fixed and immovable body, it reacts upon itself; and this must be, in a certain measure, the case with steam issuing from a boiler. But the causes which lead to variable pressures in the force of the steam are much more numerous at the seat where the steam is generated than those resulting from a difference in the working load of the engine. The phenomena of steam generation have been, perhaps, too much overlooked in regard to boiler explosion. The leakages of steam are not so numerous as the leakages of water in boilers; or where water is the resisting body, and steam the force, the force will operate by preference. It will not yield or escape unless it be impossible for the water to escape, and, in this case, the resistent then becomes the force.

"As a visible force steam cannot be said to exist. It is the name only for an effect produced in certain atmospheres by the operation of heat. In other words, steam is water and heat together—simply water and heat. If this heat could be conveyed as effectually into the same situation by any other means, the same results might be expected to follow, viz., the expansion of air into force or pressure.

"It is worthy of being borne in mind that water cannot be decomposed by heat. At all the stages of evaporation through which it passes it is normally present and has assumed no new qualities whatever. But the most important illustration perhaps of this parting with, and reassumption of the natural properties of bodies is that exemplified in the conversion of water into steam, and the reconversion of steam into water. Whatever may be the nature of the change caused in a mass of water by its absorption of heat or the passage of heat through it escaping at its surface in the form of bubbles, it is held to be impracticable to reduce steam to water again without the absence of heat. Now it is commonly known that a quantity of water placed under the receiver of an air pump will, as the exhaust is carried on, appear to evaporate with great violence. The resemblance to the phenomena observed in the generation of steam is in this case very marked and singular. The water will appear to have become condensed on the inner surfaces of the dome, and the vessel containing the water may be entirely emptied by continuing the process. The influence of heat in producing steam is scarcely yet rendered sufficiently intelligible to lead to any opinion more reasonable than that it must be taken away to re-establish those conditions which it had apparently changed. The tendency of heat applied to the bottom of a boiler containing water is to pass through the metal and the mass of water, and out again through the upper surface of the metal into the air. It is curious that the manner in which heat should be conveyed through water is in the form of cellular spheres. Certain particles of water cohere so firmly round an increment of heat and in such order that they effectually prevent its assuming any other form but a spherical one, and this minute ascending globe presenting arches on all sides to the pressures by which it is encompassed rises unhurt through a mass of any quantity. Similar results may be witnessed in cellular globes formed without heat, some of which, although presenting a large area to the pressure of the atmosphere, and being only 1-10,000th of an inch in thickness, retain the form of a globe until their contents become decomposed and eventually decompose the substance of which the spheres themselves are formed.

"*It could be fairly* assumed that if any force expanding equally, and in all directions from a point, could be introduced within one of these spheres, unless the elements of the force were liable to decompose the medium within which the expansion occurred, would always retain the form of a globe; but, as a proof of the variable expansion of steam, it may be remarked that heat begins to ascend through water in forms representing the sections of a cone. It is not uncommon to observe innumerable bubbles floating about on the surface of boiling water, some of which retain their shape for several seconds, during which time they have a motion through space of twenty or thirty times their diameters. The cause of this motion is very singular, because it proves that at times heat can disturb a great quantity or weight of water by the simple act of rising through it—whereas, it is commonly supposed that its levity is so great, that it would have no more effect upon the water than a balloon would have upon the atmosphere in ascending through it. When these globules of heat explode, the heat they had contained becomes diffused over a larger area, by taking up new situations in the smaller interstices, between the gases which are above the water line in the boiler. In proportion as the temperature of the steam space increases, the gases expand, and the interstices between them become diminished in size. Thus the heat is gradually forced within limits which continue to grow less and less until such forces of compression and resistance are reached between it and the water and material of the boiler, that the generation of more steam must be arrested, or the boiler must necessarily give way. When it is considered how great the difference would be in the size of a globule of heat when bound by and liberated from the pressure of the mass through which it has to ascend to become operative as force, it is rather astonishing that a greater number of boiler explosions do not occur.

"Yet, probably, there are not many cases where the force of the steam, at the moment of an explosion, has ever nearly approached the measure of the resistance of the boiler, and, as already observed, it is not where the steam has reached any unusual pressure that we are to look for the necessary explosion of boilers. Mr. D. R. Clark, a gentleman who appears to have given some attention to the subject of boiler explosion, stated a few years since *when the subject was inviting* very serious attention, that the percussive force of the steam suddenly disengaged from the heated water in a boiler acting against the material of the boiler, could not be adduced in explanation, and as the cause of the peculiar violence of the result of the explosion. Mr. Clark considered that the sudden dispersion and projection of the water in the boiler against the boundary surfaces of the boiler was the cause of this violence, the dispersion being caused by the momentary generation of steam throughout the mass of the water, and its efforts to escape. It was alleged by the same writer that the steam carried the water before it, and that the combined momentum of the steam and the water carried them like shot through and amongst the bounding surfaces, and deformed or shattered them in a manner not to be accounted for by single overpressure, or by simple momentum of steam. This forms one of the more ingenious but illogical explanations offered concerning violent boiler explosions. Whoever has witnessed the ascension of heat through water must have noticed that it is absolutely impossible for a single globule of heat to leave the water line. Nothing but the heat is suffered to get free, and this carries only increase of temperature to the steam space. Moreover, a spherical body can never impart velocity to a liquid. A shot discharged vertically into a vessel containing water will flatten, and in sinking cause a rise at the circumference of the vessel in proportion to the quantity of water it has displaced, whereas if it were true that heat or steam could project water against the inner surfaces of a boiler, the shot should carry a column of water through the vessel that held it. It is probably more obvious that a body not capable of holding water upon its surface cannot project it with force, but rather pushes through it, and suffers the water to subside about it. Thus this cannot reasonably be alleged as a sufficient cause for the occasional violence of the explosion of boilers. But supposing that in the generation of steam the decomposition of water proceeds so far that one of its constituent gases is disengaged, and the other retained, we then reach conditions favourable to this violence. It would perhaps be well worthy of experiment to ascertain how far some preparation capable of rapidly absorbing oxygen would not prevent boiler incrustations, because oxygen is so dense that it may be poured from one vessel to another in the open air, while hydrogen will cause a weighted balloon to ascend. It is probable therefore that they do not operate together in what is called steam power, but that the lighter gas only is set free. If heated hydrogen be brought in contact with air an explosion is inevitable, and this fact may go some way towards accounting for incipient combustion. If it be admitted also that gases may pass through the material of a boiler it will be then seen that the conditions of explosion are imminent, and only await some electrical motion to set them in force. This is given by the starting of the engine which exhausts the steam space of the boiler, and suffers the air to enter when an explosion results. It would not be devoid of interest to discover if a boiler exploding in this way would give off a momentary flash of light, because boiler explosion may represent on a small scale some of the more wonderful phenomena of nature. Thunder follows lightning and precedes a fall of rain, and in boiler explosions we have water producing thunder, and perhaps unseen lightning."

27. *Injury to Crowns of Furnaces from Shortness of Water in Boilers.*—From a recent report of the Association for the Prevention of Steam Boiler Explosions we take the following:—"Injury to furnace crowns from shortness of water appears of late to have been of very frequent occurrence. Three cases have already been reported since the commencement of the year, while two more have happened during the past month. The majority of these cases of injury occur at night-time, when the furnaces are banked up; but the first of those now under consideration took place at about half-past one in the afternoon, when the fireman was at his post. It appears that he misread the glass gauge, mistaking a small piece of white scale, which clung to the inside of the tube, for the surface of the water, and was not undeceived until being alarmed by hearing a cracking and thudding noise inside the boiler, as well as by noticing that the steam began to rush out at the furnace-mouth, angle irons, and at the transverse seam of rivets in the front end plate, he called the engineman, who at once blew the glass gauge through, and discovered that the boiler was short of water. The engineman promptly put down the damper, and drew the fire, just in time to prevent explosion, but not before the furnace crowns were very seriously *drawn out of shape.*

"The boiler was of the internally-fired two-flued class, and was one of a series of seven, all of which worked at a pressure of 60 lb. per square inch, with the exception of the one under consideration, which was used for heating the mill, and only worked at 10 lb. Had the boiler been working at the same pressure as the remainder, explosion, it is thought, would have been inevitable.

"It has been frequently recommended in previous reports that every boiler should be fitted with a duplicate glass water gauge, and in support of this it may be pointed out that the only boiler in the series referred to above which had but one water gauge was the one to which the injury occurred. Had it been fitted with two gauges, so that each would have acted as a check upon the other, it must be clear to all that the probability of mistake would have been considerably reduced, if not altogether removed.

"It has appeared on my rounds of inspection that there is more 'method' than is generally acknowledged in the occurrence of these mistakes and accidents as they are called, for certain it is that they happen more frequently at that class of works where order and general cleanliness are considered as superfluities, than where everything is, as a matter of principle, kept up in the highest style of efficiency; and many I feel will agree with me, that it is important that a boiler attendant should be induced to take a satisfaction in the appearance and external condition of his boiler and all its fittings. A fireman who took a pride in keeping his boiler-front in good order, the water-gauge glass transparent, the brass work clean and bright, and the taps correct, would scarcely have had so untrained an eye as to have mistaken, as in the case just referred to, a dead speck of scale for a column of water, which should have been alive with motion; and it is thought that the orderly keeping and appearance of a firing space and boiler-front should by no means be regarded as a matter of useless refinement, but rather as a measure of positive safety.

"The second case of injury through shortness of water occurred at night-time, when the fires were banked up, and the boiler was in charge of the watchman. The boiler had two furnaces, but one only being charged at the time the other escaped.

"Both the boilers referred to above were fitted with fusible plugs, and which it will be seen proved as useless in both these cases as they did in the three, particulars of which were given in the last report. The experience of this Association with low-water safety valves, which allow the steam to escape as soon as the water falls below a fixed level, certainly shows they are more reliable than fusible plugs."

28. *Defects of Boiler Construction.*—From the report of the same Association we take the following. "The construction of some of the boilers lately enrolled in the Association has been found to be very imperfect. Three of them have proved to be as much as a foot oval in the furnace flues, and six inches in the shell, the major axis being horizontal. This is a very imperfect arrangement. Both the shells and internal flues of boilers, unless mainly or entirely dependent on stays, should be made truly circular, since a slight departure from this shape materially weakens them; and although when oval they may be able for a time to withstand the pressure, yet a change of form takes place in them whenever the steam is got up or let down, which has a very weakening effect, and soon wears out the plates. This, in locomotive boilers, leads to internal grooving, which is so fruitful a cause of their explosion. Three other boilers, which were of the hot-water circulating description, for the purpose of heating and ventilating, although of a large size, were not fitted with any safety-valves, while the inlet and outlet pipes could both be closed at the same time, so that the pressure could be bottled up inside the boiler while the fire was in action. Under these circumstances, with anything like a brisk fire, explosion would, in a very short space of time, be clearly inevitable."

29. *Shortness of water in a boiler not essential to overheating of the plates.*—"This," says a recent writer, "is by no means essential to the overheating of the plates in a boiler when they are played upon by an intense fire, and the flames allowed to impinge locally, especially if the water be not good; and many cases have been met with in which, under these circumstances, plates have become overheated, although there has been plenty of water in the boiler at the time. In the present instance, the flames from the large fire-grate—which was fed with coal instead of slack, in order to raise more steam—played directly upon the vertical side of the boiler, and just at the part where the rupture occurred, while the water contained a good deal of loose sludgy deposit, and was found frequently to foam up, and cause the

boiler to prime. In vertical heating surfaces the steam is apt to cling to the plates, and to creep between them and the water. This, in the upright single flue, internally-fired furnace boiler, in frequent use at iron-works, has been found to have such an injurious effect upon the flue-tube, and lead to so many collapses, that this description of boiler has in many cases been discarded. There is, therefore, every probability that the overheating was due, not to a deficiency in the supply of the water, but to its being driven away from the plates by the rapid ebullition of steam within the boiler, caused by furious firing, and the too local impingement of the flames upon a vertical surface, combined with the use of sludgy water. This view is corroborated by the fact that, when overheating occurs in consequence of ordinary shortness of water, the plates are injured in a line parallel with its surface, whereas in this case they both bulged and rent in a line at right angles to it, and for a length of as much as 3 ft. 6 in. So that the statement of the fireman may after all be correct, that there was plenty of water in the boiler at the time of the explosion, while its occurrence is only another illustration of the dangerous character of these externally-fired, upright furnace boilers."

30. *Troubles incident to Steam Boilers.*—The two following articles we take from the "Scientific American."

"'I don't see what is the matter with my boiler,' said a friend recently, 'it used to make steam enough, but now it is all I can do to run the engine through the day.' Upon having an examination, the mystery was found to consist of ashes in the smoke box and soot in the tubes; simple enough, certainly. The cure was, a shovel and half an hour's labour.

"We receive frequently elaborate descriptions of boilers and engines by mail, giving full dimensions of each, with statements of the length of time they have run together, with a request to state (generally by return mail) the cause of their decay and general failure after years of service.

"Many people have an idea, apparently, that a steam engine loses some portion of its vitality every year in some unknown way, so that its decline and fall is simply a question of time. This is true where no care is taken of machinery, but, with intelligent supervision, and repairs when needed, a steam engine *one hundred* years old will be as good as the first day it took steam. It is as unreasonable to expect a steam engine to run continually without repair and inspection, as for a human being to exist without eating. A little reflection would show that if a steam engine has run for a term of years, doing the same work continually, the failure, if there be any, arises from natural causes, and that examination of it by a competent person would be the course to adopt.

"It often happens that shafting gets out of line in a shop, and that the machines generally are disordered in their relation with the power which drives them. Where this is the case, lining up the shafting and setting up the machines again would effect a great saving of power and fuel. It also happens that boilers sometimes give out, or cease to make steam freely, from the destruction of the draught.

"If one building be erected by the side of another the draught of the chimney will be affected when the wind is in a certain direction, and this in spite of the general cleanliness and good condition of the boiler. The remedy for this is to increase the height of the chimney or put in artificial draught.

"It is also frequently the case where pine wood or bituminous coal is used for fuel that a resinous deposit forms on the inside of the tubes, to the very great detriment of the steaming qualities of the boilers. It is extremely difficult to remove this, as it is composed of soot and resin, and adheres to the iron with great tenacity. A whalebone brush is sometimes employed; also a brush made of steel wire, but these instruments merely scratch the surface of the deposit without removing it. It has occurred to us that a strong, hot solution of potash might be used with good effect in this case, and we recommend a trial of it at least. It cannot hurt the boiler externally, and is so easily tried that it should be.

"Another acquaintance, some time since, called our attention to his boiler and engine, the boiler failing to make steam sufficiently, although in size it was ample. The defect here was in the setting. The boiler, an ordinary cylinder, was set on top of two brick walls, as the cover would be laid on a box, and the fireplace was simply a gaping cavern, in the further end of which the throat of the chimney loomed wide and voracious. If all the heat of Vesuvius in *eruption* were turned under the boiler it would hardly make steam enough in its condition. The steam would have been made in the chimney, for that was where the heat went, and its effect on the boiler seemed more like a passing favour than any actual duty it was bound to perform. When the furnace doors were opened a roaring wind passed through them, and the blaze went far up the chimney. The remedy in this case was to lessen or obstruct the draught; to add a bridge wall five or six feet from the furnace door, and to put a damper in the chimney, so as to arrest the heat when desired.

"But lately we received a letter from a party desiring to be informed what size engine a boiler of certain dimensions would drive. He added, on closing, 'If the boiler is not large enough it can be lengthened.' Not large enough for what? the engine it would drive? This seems like a hasty inquiry.

"As has been recently pointed out, the field for improvement is very wide. The proportion of heat utilized to that driven off or lost is very little—hardly one-tenth—and this waste is going on continually. Of course the quantity differs in different boilers, and can be greatly lessened by good management, but that great slovenliness in the use of fuel, and great indifference prevails on the part of proprietors toward getting competent engineers to attend their boilers, is apparent to any intelligent observer."

31. *Field for Improvement in Steam Boilers.*—"The boiler of a steam engine costs more than the engine; and, considering the wide use and valuable service of this prime motor, there is, perhaps, with the single exception of the plough, no instrument of more importance. There is, perhaps, also, notwithstanding all the inventive faculty and experiment that have been expended upon it, no instrument more imperfect. A boiler of ideal perfection should secure complete combustion of the fuel, so as to obtain all the heat which the coal will yield; it should transfer this heat to the water to form steam, and it should hold the steam in absolute security. In practice, very few boilers effect complete combustion of the fuel, and none secure the transfer of nearly all the heat to the water.

"When anthracite coal is the fuel used, the only portion of it which is of any value is its carbon. The burning is the combining of this carbon with the oxygen of the atmosphere. Carbon combines with oxygen in two proportions—one atom of carbon combining with one atom of oxygen to form carbonic oxide, and one atom of carbon combining with two of oxygen to form carbonic acid. According to the experiments of Favre and Silberman, one pound of carbon, burned to carbonic oxide, will raise the temperature one degree, of Fahrenheit's scale, of 4,451 lbs. of water, while a pound of carbon, completely burned to carbonic acid, will heat one degree Fahr. 14,544 lbs. of water. Hence, coal burned only to carbonic oxide generates less than one-third of the heat of which it is capable. When coal is burned with an insufficient supply of air, either the whole or a portion of the product of combustion is carbonic oxide.

"But the greatest loss of heat in steam boilers is the failure to secure the transfer of all the heat generated from the products of combustion to the water. In order to effect this as nearly as possible the tubes should have the thinnest walls practicable, as we recently pointed out. It is also quite as important that the walls of the fire-box should be of thin plate.

"Heat is radiated from all substances with a rapidity proportioned to their temperature. When, therefore, two bodies of different temperatures are placed in contiguity, the warmer will send its heat into the other more rapidly than it will receive heat from the other in return, consequently the cooler will be warmed with a rapidity proportioned to the difference in the temperatures of the two. The same law applies to the transfer of heat by conduction from one body to another; it takes place with a rapidity in proportion to the difference of the temperatures.

"Suppose we have a fire-box plate four inches in thickness, with fire on one side and water on the other; the surface next the fire may be red-hot, while that next the water is only 250 or 300 degrees. There being, then, but little difference between the temperature of the gaseous products of combustion and that of the contiguous surface of iron, the transfer of heat from one to the other goes on slowly; and the same is the case with the transfer of heat from the interior surface to the water. In this case the products of combustion go up the chimney at a high temperature, carrying away nearly all the heat generated. If the plate is thin there can never be this great difference in the temperature of the two surfaces—the surface next the fire will be cooler *and that next the water* will be hotter; the transfer of heat will, therefore, be more rapid, and the rapidity will be in proportion to the thinness of the plate.

"The transfer will also be proportioned to the rapidity of the circulation. Water is one of the poorest conductors of heat, and if a stratum next the plate remains in its position, so soon as it is heated to the temperature of the plate the transfer of heat ceases, or goes on with the slowness with which heat is conducted away by the water; but if the instant a particle of water is heated, it is replaced by the coldest one in the boiler, the transfer of heat goes on with the greatest possible rapidity. In plain kettles, heated from the bottom, the ebullition creates a very active circulation; but in small tubes, if the bubbles of steam are passing in one direction and the water in the opposite, the circulation is seriously impeded. Inclining the tubes, as in Dickerson's boiler, is an exceedingly simple and effectual means for producing the most active circulation, and is probably destined to be very generally adopted.

"The most effectual plan, however, for insuring the transfer of all the surplus heat is to pass the products of combustion right into the water. This plan has been tried on a steamboat on the North River—the *John Faron*—but was abandoned in consequence of the accumulation of ashes in the boiler; it would seem, however, that this difficulty, being merely mechanical, ought to be overcome, in view of the great advantages to be realized. It is true that both the air and the fuel would require to be introduced against the pressure of the steam, but as the air would be worked through the cylinder, its expansive force would doubtless be sufficient to drive the air pump. Prof. Seely has suggested that the carbonic acid might be absorbed by the steam, so that no increased tension would result from it; but this certainly would not be the case with the nitrogen, and its expansion would at least prevent any loss of power. This plan would give not only the most effective and economical, but also the simplest and cheapest, of all conceivable boilers. All that would be required would be a plain cylinder with an inclosed fire-box, without any tubes, stays or other costly adjuncts; and, as no heat would pass through the shell, it might be of any thickness necessary to insure absolute safety from explosion.

"All that is required to make this great improvement practicable is some simple and effectual plan for preventing ashes from going into the boiler, or for readily blowing them out after they are introduced."

32. *Pitting of Boiler Plates.*—"This dangerous deterioration of the plates of steam boilers has been traced to several sources, the most important and most usual being the voltaic action due to the different electric condition of the scraps worked into the plates, to the contact of different kinds of plates, or to that of cast and wrought iron: the water, containing more or less of chemical compounds in solution, causes the electro-positive metal of the galvanic battery thus constituted to be removed with great rapidity. The use of an electro-homogeneous metal—cast steel, for example—in the boiler plates naturally prevents pitting, as the galvanic action no longer occurs, for want of a third element. On the other hand, the effect is greatly augmented when the water is unusually acid, or otherwise corrosive, from peculiar circumstances. Hydrochloric acid is frequently present in marine boilers, and may even be detected in the steam escaping from them. When the fuel is sulphurous, the feed-water, or the water from a leak, will, if exposed to it, absorb thirty volumes of sulphurous acid, and the effect of this in furrowing may easily be conceived."

33. *On Priming.*—In the "Engineer," under date December 1st 1865, there is a lengthy and most suggestive article on this subject. We regret that we have space only for the following, and must therefore refer the reader to the article. After describing the remarkable phenomena connected with priming and the puzzling circumstances which these bring into existence, tending to make the subject a most difficult one to deal with, and which gives rise to a remarkable diversity of opinion on it, the writer proceeds: "In point of fact it is better that the investigator should endeavour to divest himself of every impression conveyed by a knowledge of those conflicting phenomena, and endeavour to single out as far as possible those facts which invariably hold good or nearly so under all circumstances. Unfortunately these are not very numerous, but they are very simple. As a rule, a large steam space reduces priming: in the first place by giving the water time to separate from the steam, in the second by preventing sudden changes in the pressure above its surface. Again,

a large water surface acts beneficially by providing an extensive area from which the steam can eliminate itself quickly without carrying up much water with it. Furthermore, in a steam boiler, as in a well-managed household, there should be a place for everything, and everything should be in its place. That is to say, water should not encroach upon the steam space, nor steam on the water space, and this condition can only be secured by providing for a vigorous circulation. After all, these statements, although substantially correct, do not apparently come to much; and yet on these alone can we base any rules for the construction of boilers which shall possess the power of supplying dry or nearly dry steam.

"It may here prove useful to consider for a moment the nature of the phenomena from which priming apparently results. Priming is in conventional terms nothing more than a boiling over. The steam as it is generated, instead of escaping freely from the water, is entangled with it, and carries over in its grasp a certain portion of the fluid. Now it is not very easy to determine the exact condition of a mass of water heated up to the boiling point proper to the pressure to which it is subjected. We know that steam is produced by the separation of the molecules of the fluid, and that a comparatively small addition of caloric will suffice to convert a portion of a mass of water already on the verge of ebullition into steam. The elastic fluid is in practice produced as close as possible to—in short in contact with—the heated surfaces of the furnaces and tubes; but it is only by a species of accident that any one portion of the mass of water comes into this contact to the exclusion of any other portion. It is tolerably clear that, so to speak, the whole mass of water must be in a condition approaching that of unstable equilibrium, and that it is only prevented from all ultimately flashing into steam at once by the fact that it is a comparatively slow conductor of heat, that different portions of the mass are better situated for taking up heat than others, and that those so taking it up at once become steam, and depart to the surface. Still there is not much room to doubt that the molecules of heated water have lost some of the power of that grasp with which they clung to each other while cold, and that as a result steam just *formed can hardly* fail to carry with it something which is not exactly water nor yet steam—a finely divided mist in fact, hovering on the verge of either condition; and this, unless time be allowed for its precipitation, finds its way to the cylinder as one form of priming. The process by which large bodies of water find their way there is somewhat different. The boiling point at the bottom of a deep boiler is sensibly higher than near the surface, and thus the fluid may become heated, if detained in contact with a furnace crown, to a point higher than that at which it would boil near the surface. Where the circulation is imperfect water may thus be detained for an appreciable space of time, and on subsequently rising it will, possibly, when still 6 in. or 8 in. from the surface, flash into steam, carrying the superincumbent water with it, lifting it as it were in a sheet from the water below, and hurling it directly towards the point of least resistance—the orifice of the steam pipe. Once within this, of course there is no return. The priming which ensues the moment a vessel leaves the sea and begins to take fresh water into her boilers may, perhaps, result from a somewhat different train of events. The fresh water entering rises through a mass of liquid, which, although not itself necessarily boiling, is nevertheless heated to a much higher point than that at which fresh water would boil under the same pressure. The result is that the feed absorbs heat directly from the salt water instead of waiting its turn to come into contact with the heated iron, and flying into steam at once, carries much water with it. Phenomena of a similar character, but magnified in degree, can be produced by injecting small quantities of water beneath the surface of a melted fusible metal such as tin. Some time may elapse before the solution of salt is weakened by blowing off, and so long as any decided difference in density exists between the contents of the boiler and the feed so long will priming continue as a rule. We lay no claim to originality in enunciating this theory. It is due, we believe, to John Bourne, and we repeat it here because we think it the most satisfactory which has yet been advanced. But neither this, nor the theory by which it is preceded, can reconcile the hopelessly discordant statements advanced by engineers to which we alluded in the first paragraph of this article."

DIVISION SECOND.

FUEL—FURNACES—SMOKE CONSUMPTION.

SECTION FIRST—FUEL.

34. *Theoretical and Practical Value of Fuel.*—It is a somewhat suggestive circumstance that, while attention has been directed in a very marked manner to the mechanism of the steam engine, comparatively little has been given to the fuel which is used to raise the steam upon which the economical working of this depends. The difference, indeed, between the theoretical or assumed value of fuel and the value we get out of it in practice is very marked, and in no way satisfactory. The average practical value falls short, very short indeed, of the theoretical value of coal. That there is a fault somewhere in the modes in use for consuming coal is evident enough; in this, as in other departments, there is an abuse as well as a use of coal. In a very suggestive article by Mr. Lewis Thompson, the well-known chemist, in Newton's London Journal of Arts, under date Nov. 1, 1865, and under title "On the use and abuse of coal in our manufactories," there are some points bearing closely on the subject now under consideration. After pointing out that any improvement in the production or application of artificial heat would constitute one of the most profitable inventions of the day—and after stating, in order to the proper understanding of the subject, that he would separate the chemical from the mechanical part of the argument, Mr. Thompson thus proceeds. "In burning coal we really burn two substances which differ greatly in their combustible qualities; that is to say, we burn hydrogen and carbon, the first of which will oxidise or burn under conditions that leave the latter unburnt. Then, again, we practically attempt to burn coal in oxygen gas diluted with nearly four times its bulk of nitrogen gas; that is to say, in atmospheric air. But the chemical impediments to perfect combustion created by such an attempt, amount to this: firstly, the hydrogen of the coal being more combustible than the carbon, has a disposition to seize upon the *oxygen of the* air, and leave the carbon unburnt; secondly, the

nitrogen of the air, by diluting the effect of the oxygen, reduces the intensity of the heat given off by the hydrogen, so as to bring the temperature below that point at which the carbon from coal will burn; therefore, chemically speaking, a double tendency exists to leave the carbon of the coal unconsumed—a fact which we see daily exemplified by the formation of soot. There is, however, a much more serious question than the production of soot connected with the difficulties of perfect combustion, and this arises out of the disposition of red-hot carbon to decompose carbonic acid gas and convert it into carbonic oxide gas, with the absorption of an immense amount of caloric, or, in other words, with the generation of much cold. For example, if one pint of carbonic acid gas is subjected for a short time to the action of a quantity of red-hot coke, the gas is decomposed and converted into two pints of carbonic oxide gas, and during this process a vast amount of heat is rendered latent or lost; so that it is practically possible for us to take two equal quantities of coke, and having burnt one of these, then to pass the resulting carbonic acid gas over the other portion of coke in such a manner as to absorb or render latent, an amount of heat almost equal to the whole of the heat given off by the first portion of coke. To speak plainly, it is possible to burn coal so as to obtain little or no heat from its combustion, in consequence of the formation of carbonic oxide gas; and this circumstance we most earnestly wish to impress upon the attention of the public; for the production of unburnt coal or soot is a defect at once visible to the eye, and therefore calculated to attract the notice of every person; but the formation of an invisible gas like carbonic oxide, is a defect which may and does go on to an extent far beyond even the imagination of the most careful manufacturer, as we shall hereafter show by a reference to actual experiments. With regard to the mechanical difficulties connected with combustion, these are very much dependent upon the radiation and conduction of heat by the different substances employed in the construction of our furnaces and the steam-boilers placed over them. As, however, the principles of calorific radiation and conduction are almost totally unknown to the constructors of our furnaces, it need not surprise us to find that much of the heat produced by our fuel is lost or misapplied in the *generation of steam.* The radiation of heat takes place under such laws that its effect diminishes as the square of the distance: consequently, if a fire at the distance of one foot from a boiler is able to boil off 16 lbs. per minute of water by radiation, at a distance of two feet, it will boil off only 4 lbs., and at four feet but 1 lb. of water per minute.

"In respect to the conduction of heat, it might at first sight appear that in this particular we are limited to the conducting powers of water and malleable iron; but a very slight examination of the practical working of the question soon teaches us that the conducting power of the iron is set at nought by the disposition of calcareous matter having a conducting power scarcely equal to $\frac{1}{50}$th of that possessed by iron. To render our remarks intelligible, we say that by actual experiment we have proved that if an iron boiler 1 inch thick will boil off 50 lbs. of water per minute, the same boiler having within it a calcareous crust 1 inch thick, will boil off only about 1 lb. of water per minute, the heat applied to the exterior of the boiler being equal in both cases. Hence, then, we see that it is possible so to place a boiler as to lose by radiation fifteen parts out of sixteen of the heat applied to it; and again, it is possible, by permitting the incrustation of a boiler, so to diminish the conducting power of the iron as to lose forty-nine parts out of fifty of the heat applied to it. No doubt these are extreme calculations; but what, after all, is the real condition of the case? It is this, that practically at this moment in our manufactories, with a kind of coal capable of converting fifteen times its weight of water into steam, only 6 lbs. of steam are raised per 1 lb. of coal consumed; in other words, more than one-half of the coal burnt under our steam boilers is thrown into the air and lost. Nor is this a hasty assertion, for it is based upon the daily working of several different steam boilers in London, Liverpool, Manchester, Newcastle-on-Tyne, and Glasgow.

"Having thus far pointed out the impediments which chemically and mechanically interfere with the production and application of the heat from coal, we will now relate what we ourselves have done within the last two years by way of removing these impediments. To ascertain the extent of the loss created by imperfect combustion in our furnaces, it became necessary to examine the *composition* of the air passing from the chimney. Of course we had no difficulty in collecting a portion of this air, which was then analysed in the following manner:—From a measured quantity of it, the carbonic acid was abstracted by a solution of caustic potash; the oxygen was then removed by adding a little pyrogallic acid to the potash solution; this solution was then poured out and replaced by a solution of the proto-chloride of copper in muriatic acid, so as to absorb the carbonic oxide, after which, in some cases, the remaining air or gas was passed over red hot oxide of copper contained in a glass tube, with a view to discover the quantity of hydrogen contained in it. It might have been anticipated that the results from different chimneys and at different periods of the charge of fuel would have been exceedingly various and contradictory; but although not absolutely uniform, our results present a general agreement in the most important features that cannot be regarded as otherwise than satisfactory so far as the object of our inquiry is concerned. After making upwards of 370 experiments upon the air from 42 different chimneys, we have come to this general conclusion—that, except immediately after a charge of coal, the air from a *well*-fed furnace contains no appreciable amount of hydrogen or hydro-carbon, or sulphurous acid; that the quantity of carbonic acid gas is about 6 per cent., the quantity of oxygen gas about 9 per cent., and the quantity of carbonic oxide gas about 8 per cent., thus leaving us to infer that about 9 per cent. of the oxygen in atmospheric air is consumed by the hydrogen of the coal. Hence it appears, that in respect to the production of heat in furnaces, 9 parts of the oxygen of the air escape unacted on; and of the remaining 12 parts 6 are converted into carbonic acid, 2 combine with the hydrogen to form water, and 4 are carried off in the shape of carbonic oxide gas. Consequently, we may say that out of every 12 degrees of heat which ought to be produced by our fuel 4 degrees are directly abstracted by the generation of carbonic oxide gas, and probably not less than 1 degree in addition is absorbed by the gas and rendered latent; therefore it is evident by the analysis of the air from our furnace chimneys, that $\frac{5}{12}$ths of the fuel consumed upon the furnace bars is lost as carbonic oxide, and thrown uselessly out at the chimney. But we have seen that practically, in the generation of steam, only $\frac{6}{15}$ths of the total *calorific power of the coal* is employed or absorbed by the steam produced; and if we allow $\frac{1}{15}$th of this calorific power as a necessary means for creating a draught in the chimney, we shall still have $\frac{8}{15}$ths unemployed or lost: consequently, in a practical point of view, it appears that heat is carried off otherwise than by the action of the carbonic oxide gas. To render the amount of this loss intelligible, we must reduce our fractions to a common denominator; that is $\frac{5}{12}$ to $\frac{75}{180}$ and $\frac{8}{15}$ to $\frac{96}{180}$, from which we see that $\frac{21}{180}$ths of the heat are lost by radiation and imperfect conduction. If, then, we assume that any given quantity of coal, when burnt in our steam-boiler furnaces, will give out 180 degrees of heat, that heat will be thus distributed:—

"Usefully employed in raising steam . .	84	degrees.
Lost from carbonic oxide gas . . .	75	,,
Lost from radiation and imperfect conduction .	21	,,
Total	180	

"Merely to point out an imperfection is, after all, but a very sorry qualification, and therefore we have tried to go a little further; we have tried to improve our steam-boiler furnaces, and apparently with some success. Many years ago Dr. Kennedy asserted that the hottest part of a furnace is one inch above the bars, and this is true with furnaces having a slow draught; but with a quick draught it is otherwise; and from pyrometrical experiments made in boiler furnaces, we have found that the hottest point is between two and three inches above the bars of the furnace: consequently, we recommend that never more than four nor less than two inches in depth of fuel be upon the bars of a steam-boiler furnace in action. If less than two inches be upon the bars, much useless air will pass through the fuel, and carry off the heat; if more than four inches be upon the bars, great part of the carbonic acid produced near the bottom of the fuel will be decomposed near the top, and converted into carbonic oxide gas with the destruction or absorption of a vast amount of heat, thus rendered latent. From what we have stated in regard to the radiation of heat, it is clear that the boiler ought to be placed as near to the fire as possible, and by so doing this additional advantage is gained; it prevents a lazy stoker from overcharging his furnace bars and thus producing an extra amount of *carbonic oxide.* Great stress is laid by some stokers upon the burning away of the boiler in consequence of this close proximity of the fire: it is not, however, the nearness of the fire, but the thickness of the internal crustation, which causes the burning away of the boiler; and this we will hereafter explain. At present, we return to the question of combustion. From our analyses of the air in the chimneys, it is evident that sufficient oxygen exists in it to convert the carbonic oxide into carbonic acid, or, in other words, to completely burn the whole of the fuel: why, then, is the carbonic oxide not burnt? This arises from two causes: the positively anti-inflammatory nature of carbonic acid gas, and the cooling influence of the nitrogen gas and steam boiler, by which the temperature of the mixed air is cooled below that point at which carbonic oxide gas will take fire and burn. Now, although we cannot alter the positive power of the carbonic acid, we may overcome the cooling influence of the other agents: and this has been most successfully effected in the following manner:—A cast-iron tube, 4 inches in diameter, was fixed in the lower part of the chimney and made to communicate with the external air by means of a bend, at a height of 6 feet from the ground; to the lower end of this tube a similar tube was fixed, and this was made to pass horizontally under the boiler about 1 inch from it. The horizontal part of the tube terminated immediately over the back of the furnace, and was joined to the middle of a cross-piece of similar tubing; the cross-piece being as long as the width of the furnace and closed at the ends, but pierced all along with a number of $\frac{1}{8}$-inch holes at the distance of 2 inches from each other. The theory of the action of this tube is very simple; from its position it becomes heated throughout its whole length, and the cross-piece in particular becomes red-hot; the draught of the furnace causes the air to enter at the bend or open end, and, traversing the tube, this air issues in a red-hot state from the holes in the cross-piece, where it meets and burns the carbonic oxide gas as fast as this is generated by the fuel. The result is, that in four steam boilers where this contrivance has been applied, the steam is generated much more readily than usual, and a manifest economy of coal is taking place. It is necessary, however, for us to remark, that another expedient has also been adopted in the case of the same boilers; this relates to the *prevention of incrustation*. A few careful analyses had convinced us that this incrustation is not due to carbonate of lime, but to sulphate of lime, by which the particles of carbonate of lime are cemented together and converted into a crust. To prevent the formation of this crust, it is necessary only to destroy the sulphate of lime, which is easily done by adding 1 lb. of common carbonate of soda (washerwoman's soda) to every 300 gallons of water supplied to the boiler. This converts the whole of the lime into carbonate, which has no tendency to agglutinate, but remains as a semi-crystalline powder, that may either be collected by placing an empty vessel in the boiler, or it may be blown out at intervals in the form of milky fluid. In both cases the conducting power of the iron boiler is preserved, which not only facilitates the development of steam, but prevents the burning or oxidisement of the boiler. That it must also prevent or diminish the number of explosions is more than probable."

35. *The evaporative powers of different coals in practice* appears, says Mr. P. Nursey in a paper on "Fuel" recently read before the Society of Engineers, to be nearly proportionate to the quantity of carbon they possess: bituminous coal is, therefore, less efficacious than coal consisting chiefly of pure carbon. A pound of the best Welsh or anthracite coal is capable of raising from 9½ lb. to 10 lb. of water from 212 deg. into steam; whereas a pound of the best Newcastle is incapable of raising more than about 8½ lb. of water from 212 deg. into steam. Mr. Wicksteed gives the following table of the comparative evaporative powers of various coals when burned under boilers :—

Description of Coal.	Water evaporated per pound of coal	Comparative cost per ton in London.	
No.	Lbs.	s.	d.
1. The best Welsh,	9·493	17	11
2. Anthracite,	9·014	17	0
3. Best small, Newcastle,	8·524	16	1
4. Average, small, do.,	8·074	15	2¾
5. Average, Welsh.	8·045	15	2¼
6. Coke from Gas-works,	7·908	14	11
7. Coke and small, Newcastle, ½ and ½,	7·897	14	10¾
8. Welsh and Newcastle mixed, ½ and ½,	7·865	14	10
9. Derbyshire, and small Newcastle, ½ and ½,	7·710	14	6½
10. Average, large, Newcastle,	7·658	14	5½
11. Derbyshire,	6·772	12	9¼
12. Blythe, marine, Northumberland,	6·600	12	5¼

36. *The Calorific Value of Fuel.*—In an article in the "Mechanics' Magazine," under date Feb. 10th, 1865, many points of value in connection with this subject are given. Space only permits us to give an abstract of the article, referring the reader to the No. of the Magazine in which it appears for the remainder. After naming the three natural fuels, wood, peat, and coal, and the two artificial ones, charcoal and coke, making up the five fuels generally employed; and after briefly explaining the nature of combustion, the writer proceeds to detail the *theoretical considerations* affecting the value of fuel, and then sums up the whole. "The conclusions to be drawn from these theoretical considerations are, in the first place, that all fuels have not the same calorific value, and this leads to a consideration of the circumstances which influence its steam-raising power and its thermal effect. With regard to the first point, a loss of heat occurs in the furnace by the latent heat of water vapour from damp fuel, and also from the additional presence of hydrogen, and by the gaseous products of combustion escaping by the chimney at high temperatures. If the gases were arrested in their progress and applied to the purpose of heating the boiler water, the loss would be very much diminished; practically there are here difficulties in the way.

"When water passes into steam a quantity of heat becomes latent and is practically lost; hence water is the worst constituent of fuel. The conclusion, therefore, is that wood and peat are bad for fuel, inasmuch as they contain hydrogen and oxygen, which, though not in the form of water, yet by their union produce water in combustion. Again, it has been stated, that nitrogen, sulphur, and ash are undesirable in fuel; and as they take up some of the heat evolved by other constituents they might be replaced by better things. Further, the quantity of heat produced by a given fuel is not the criterion of its intensity, the temperature being influenced by the quantity and nature of the products of combustion as by the gross amount of heat evolved.

"The temperatures, as laid down in theory are not attainable in practice, inasmuch as combustion is never perfectly carried out even in the best constructed furnaces. Besides, a large amount of heat is lost by radiation; and, what is still more important, it is not possible to admit into the furnace the precise quantity of air required for perfect combustion. A much greater amount may pass through, so the available heat would be distributed over all this excess of nitrogen and oxygen, and the result would be a proportionate reduction of the temperature.

"Carbon in burning combines with oxygen to produce carbonic acid; or, if the amount of oxygen be small, carbonic oxide may be produced by a subsequent change. But the heat evolved in the two cases differs very widely in amount. As the quantity of carbonic oxide increases, the greater the loss of heat becomes. This singular result is due to imperfect combustion, and it clearly affects both the quantity and intensity of heat obtained by burning carbon, and in practice is of importance. In calculating temperatures it has been assumed that carbon could be burnt in a quantity of air containing the precise amount of oxygen necessary to combine with the carbon to produce carbonic acid. But, if a large amount of carbonic acid be present, carbon cannot burn, even with plenty of oxygen, so that much more air passes through the furnace than contains the quantity of oxygen necessary for converting all the carbon of the fuel into carbonic acid, and the hydrogen into water. The loss of heat, therefore, is just that required to raise the excess of air to the temperature at which it escapes from the furnace. It follows, then, that in practice the temperature may be fifty per cent. lower than in theory.

"In fuel containing hydrogen a loss of carbon may result from the formation of volatile hydro-carbons, which often escape unburned at an early stage. A distinction, therefore, is made in the practical valuation of fuel between this and fixed carbon, the steam-raising and thermal power being estimated by the fixed carbon alone. The difference between gas and steam coals is explained by this: gas coals yield hydro-carbons in large quantity, while the yield in the steam coals is small.

"Where very high temperatures are required, the fuel which should be selected ought to approach as near as possible to pure carbon in its composition, and for the reason that carbon is the best substance for the purpose. Coke gives a much higher temperature than the coal from which it is made, and charcoal than wood. Carbon requires but little oxygen for its combustion, and so produces but a small amount of carbonic acid; it does not necessitate a larger supply of nitrogen from the air; and it therefore follows that it is the best substance for producing high temperatures. Comparatively, the specific heats of nitrogen and carbonic acid are low; therefore, the products of combustion have but little weight, and it requires but a small heat to raise these products through 1 deg., and upon these two conditions a high temperature principally depends. Another point to be noticed is the absence of water as a product of carbon, which materially influences the results of combustion. Hydrogen, although producing the largest quantity of heat of any known combustible, is powerless to produce a similarly high temperature under ordinary conditions, inasmuch as it requires eight times its own weight of oxygen for combustion, and, as a consequence, twenty-seven times its own weight of atmospheric nitrogen. Further, water is the product of combustion of hydrogen, and water is the least desirable of such products, owing to its great latent and specific heat.

"We now see the reasons for making coal into coke, and wood into charcoal. Coal cannot produce a temperature equal to that obtained from coke, neither can the temperature of wood be compared with that of charcoal. And this results from the relative accession of carbon and reduction of oxygen and hydrogen in them. This must be referred to the great difference between quantity and intensity of heat. If we cannot raise sufficient steam from a boiler by the use of one ton of coal, we can easily meet the point by burning two tons; but if the fusing point of metal cannot be attained with one ton of coal, it by no means follows that any additional amount of fuel will insure the required result. The great distinction to be observed is between *quantity* and *intensity* of heat. The first of these two conditions depends upon the quantity of fuel, but the last is referred entirely to the quality of fuel. Twenty tons of coal will not give a temperature as great as that afforded by one ton of coke.

"The great difference between theoretical temperatures and those attainable in practice, is, that fuel will not burn in the precise amount of oxygen or air which chemically combines with the constituents of the fuel during combustion. The highest temperature in practice is to be obtained from any fuel to which this objection does not apply; hydrogen is practically such a combustible. The temperature attainable by the oxy-hydrogen blow-pipe exceeds that of any furnace, because, being a gas, hydrogen can be readily mixed with the precise amount of oxygen required for its combustion, which is not retarded by the water produced. The practical application of these remarks, therefore, is to enable us to determine the comparative steam-raising power or thermal effect of different varieties of the same kind of fuel. The sample which yields the best results in theory will prove the best in practice, although, for reasons given, its results in practice must fall short of those attained in theory."

37. *Petroleum as Fuel for Steam-Raising Purposes.*—Much discussion has taken place during the last year on the subject of petroleum as a fuel, and various have been the opinions promulgated respecting its value in this way; nor is the question likely to be, for some time at least, other than a "vexed" one, inasmuch as those opinions are most diverse in character—some maintaining the *pro* with as much vehemence as others are found to maintain the *con.* Space unfortunately prevents us from giving even a resumé of *all* that has appeared on the subject; but we make room for those papers which give the most if not all of the salient features of the discussion. These are generally stated in an article in the "Scientific Review," under date August 1st, 1865, entitled "Petroleum as a Steam Fuel." "The very large quantity of space occupied in steamers by the coal required on long voyages, renders it very desirable that some less bulky substitute should be found. As this substitute, according to many persons, may be obtained in petroleum, and experiments have actually been made which seem to confirm their views, we deem it advisable to place before our readers a few facts that may serve to guide them in the judgment at which they will arrive.

"In the first place, the supply of petroleum, though very great, is far from being unlimited. Very large quantities are consumed for illumination and various industrial purposes; indeed, the supply required for these alone has not yet been exceeded, as is proved by the very high price which petroleum yet maintains. The whole amount exported by America in 1863 was 27,195,240 gallons, and in 1864, 31,119,530 gallons. We need not at present take into account the quantity obtained from other sources. The price of the best varies from about £19 to £20 per ton; which is about twenty times that of coal. The inferior kinds can, no doubt, be had for about half this cost. It would, of course, become very much dearer were the demand augmented by its use as steam fuel. If we compare the amounts of conbustible matter in coal and petroleum—and this is the fair way of proceeding, since we have a right to suppose that each will, as it may, be properly burned—the advantage on the side of petroleum is not great; since coal may be considered to contain 83 per cent. carbon, 5 per cent. hydrogen, and 12 per cent. ashes; petroleum, 85 per cent. carbon, and 15 per cent. carbon, with no residue. A great saving in freight is expected from the use of petroleum; but, the specific gravity of coal being considered about 1·42, and that of petroleum 0·825, and deducting one-third of the specific gravity of the coal, on account of the interstices left by it, the spaces occupied by coal and petroleum will be as 0·825 to 0·950, or as 1 to 1·152; that is, 1,000 tons of petroleum would occupy the space required by 1,152 tons of coal: a disadvantage not compensated by the larger amount of combustible matter contained in it—their calorific capabilities being, for equal weights, in the proportion of only about 1 to 1·43, if we consider that 1 lb. of carbon evolves 14,220 units of heat, and 1 lb. of hydrogen 60,854, or more than three times as much. A large amount of the heat evolved by hydrogen is wasted on account of the great latent and specific heat of the water produced by its combustion. With the coal, some of the heat, it is true, is wasted in bringing the ashes to the temperature of the furnace, and some of the coal is lost with the ashes; also, whether the engine is actually working or not, the fire must be kept up, which is not the case when petroleum is used. Against the facts in favour of petroleum, should be borne in mind the difficulty of keeping it from communication with the atmosphere, which would cause waste, and the danger of conflagration and explosion arising from leakage, or from the use of it without extreme caution. In war, a shot through a tank containing it might cause the most lamentable effects."

On the same subject, and indeed under the same title, the Mechanics' Magazine—of date August 11th, 1865—has a paper from which we take the following extracts: "A very important question which has recently engaged attention is, whether petroleum can be substituted for coal in boiler furnaces? By some it is considered impossible, whilst others maintain that with a special boiler petroleum would produce an amount of heat in effect equal to four times its weight of coal. Captain Selwyn has recently discussed its value as a steam fuel before the Royal United Service Institution. He estimates that where a steamship is now able to carry from nine to thirteen days' fuel in the shape of coals, forty or fifty days' fuel consisting of petroleum might be carried. This estimate is based upon the assertion that mineral oil is to coal in the proportion of four and a half to one. Another advantage in the use of petroleum would consist in its being a fluid, and capable of being carried in compartments or tanks, 'which again serve, by dividing the large space now necessary for coal bunkers, to help materially in preserving or augmenting the extent to which that cellular form of structure can be carried, which is the surest and best precaution against the destructive effects of shot or rocks.' But as a set-off against this advantage we think there is the fact that petroleum is more liable to accidental ignition than coal. Red-hot shot will of course ignite coal, and there is great possibility of explosions and complete destruction of the ship, if petroleum were stored in large quantities. The remedy suggested in this respect is to lower the vapourisable effects, by distilling off the light spirit. Mr. Richardson, a fellow of the Royal Institute of British Architects, answers the question by saying, 'If a red-hot cannon-shot were to enter a tank of petroleum, it would not set it on fire; it would merely vapourise the oil. If the tank was in a ventilated place, the cold vapour would escape harmlessly; if while the oil was vapourising, a light was taken to the tank, only such superficial portion of the oil as was exposed to the air would take fire; it could be extinguished immediately by shutting off the air — there would be no explosion; but if, while the oil was on fire, the tank was upset, the larger surface of the oil exposed to the air would be one mass of flames.' So that while the danger might be materially decreased by proper precautions, there would still be the risk of a greater calamity by the combustion of oil, even deprived to a large extent of its vapourisable effects, than by the ignition of coal. Mr. Richardson asserts that no dangerous amount of vapour can escape from petroleum secured in proper iron tanks. But a small escape of vapour would be as disastrous in its effects as an escape of gas, which has often blown buildings to atoms.

Captain Selwyn believes that petroleum oil will be found to be highly preservative of iron, whether from internal corrosion, galvanically caused, or from the external fouling, which is a great defect in all iron ships. Other advantages may be enumerated. Fewer stokers would be required. The labour attendant upon getting up ashes would be abolished. The light spirit might be used as a substitute for turpentine in oil paintings. An enthusiastic American engineer estimates the saving in the use of oil as against that of coal to be more than nine-tenths in bulk, and three-quarters in expenses, in running a ship from the United States to Liverpool or China. This is, however, a statement made on the authority of a sanguine patentee. . . . The use of petroleum as steam fuel would necessitate the construction of a different kind of boiler to that now in general use. Mr. Richardson has suggested a grate which can be started in a minute. If, he says, the petroleum spirit were extracted from the oil, the fire in the grate would take longer to light, probably eight or ten minutes, but the oil would be entirely deprived of the character of spontaneous combustion. Mr. Richardson says not only that he has no fear of the spirit, but would rather it was not extracted. The oil is not explosive. When contained in iron cisterns, or metallic cases carefully closed, it might vapourise without danger. The manufacturers of these cases allow space, or have a contrivance for permitting extra vapour in a warm climate. In 1864, 81,196 barrels of refined and crude oil were imported without accident. It appears that insurance companies have considerably reduced their charges on petroleum; and the Belgian Minister of the Interior has declared that the merchandise in this oil is not to be specially regulated as a dangerous article. Mr. Prentis, a manufacturer of Birkenhead, has adopted the plan of collecting the gas evolved during the process of refining petroleum, and using it for lighting purposes. It appears that petroleum produces a gas absolutely free from impurities, and one foot of oil gas gives the light of three feet of ordinary coal gas. Mr. Richardson is very sanguine as to his expectations of the future use of petroleum instead of gas. A time may arrive, he says, when every householder, by keeping a tank of petroleum in the upper part of his dwelling, could have flame laid on to every stove in his house, as well as gas to his gaseliers, rendering him alike independent of the coal merchant and the gas company. However desirable such a revolution might be, we fear householders will long retain their prejudices against the use of petroleum, especially when stored in large quantities. Why it should not be advantageously used for locomotive purposes, we are unable to say. We agree with Mr. Mallet in his observation at the discussion on Mr. Richardson's paper, that the use of petroleum as a fuel for steamships must ultimately take place."

In the above extracts notice is specially made of Mr. Richardson's experiments on the use of petroleum. The following is part of a letter which this gentleman recently addressed to the editor of a Metropolitan Journal. "The result of the experiments with my grate at Woolwich Dockyard has more than fully confirmed the value of the oil above coal for steam fuel, as first proved by my experiments at Chelsea. Several of the naval engineers who saw the grate said it was much too small to get up steam, its superficial contents being only two feet. It was placed in position under the boiler of a powerful steam hoisting engine of fourteen horse-power, capable of being worked up to 24 h. p.; the size of its coal grate was nine feet super. With the water cold at starting, and with a consumption of only five gallons of oil, in two and a half hours it caused the steam to blow off fully; one half-hour of the time the valve fixed at 10 lb. pressure. The grate of thin cast-iron, in four separate pieces, was not sufficiently strong to bear the pressure, which was fully equal to 25 lbs., and, as it indicated weakness, I drew off the oil, about one gallon, five having been supplied. If the coal grate had been reduced to two feet super, I question whether it would have done as much in eight or ten hours. I submitted to the engineer of the yard drawings for a wrought-iron grate, to be fixed to and make part of the boiler; and I have been requested by the Admiralty to send these drawings to Woolwich for estimates to be made, so that it should be tried on a large scale. The drawings I left there this morning.

'It was in your paper that I first saw the report of Professor Fisher, of Newhaven, speaking so strongly as to the absurdity of petroleum competing against coal as steam fuel; other analytical chemists of equal eminence in England have followed suit. Im-ediately a notice appeared in the *Times* of the experiments at

Woolwich came a letter, stating that 'a very slender consideration of the character, composition, and cost of petroleum would be sufficient to show the impracticability of using it as fuel in such a case. The heating power of petroleum is certainly higher than that of coal = 1·5 : 1·0. But the price of petroleum varies from £15 to £20 per ton. . . . Now, these facts will be sufficient to convince any one of the impracticability of using petroleum as a substitute for coal in steam vessels, quite independently of any contrivance as to the mode of burning.' Almost the words of Professor Fisher. I received a letter from an eminent engineer (in the early stage of my experiments), whom I had asked to view the process, almost in the same strain; this gentleman I afterwards found was the owner of some valuable patents entirely dependent upon the use of coal as steam fuel. I can well imagine that when petroleum comes into use instead, it will cause some considerable jealous excitement. Coal mines and their monopolies are too valuable a property to let slip without a struggle. My answer to Professor Fisher, and all analytical chemists, is this: If coal could be fully utilized, their statements would be correct, but it cannot; through the present system of rapid firing one half the fuel goes off in heavy black smoke, owing to the impossibility of supplying sufficient air to effect the combustion of the gases the coal gives off when heated. By careful firing and the use of the Argand furnace, the entire prevention of smoke can be obtained, and the fuel be more fully utilized. But there is a prolific cause of waste, which is beyond the power of any Argand furnace or careful firing to cure. Coal can only be burnt by supplying it with a strong draught or current of air; it requires a tall chimney—the taller the better, because the quicker the draught. This current of air must be formed before the coal is put into the furnace; large logs of wood are fired, the furnace doors being kept open; when the coal is put in a welding heat is often obtained through the quickness of the draught. The office of the tubes and flues in the boiler is to obtain as much heat as possible from the passing current, going several hundred cubic feet per minute. When the current of heated air enters the chimney funnel it represents waste heat, and is never less than 600° F. In a late work by Mr. Wye Williams, no second authority on this subject, entitled, 'On the Steam Generating Power of Marine and Locomotive Boilers,' he details three careful experiments as to the best form of boiler to obtain the greatest amount of heat from the fuel. He gives the temperature of the waste heat to the first experiment (he calls them properly 'the escaping products in the chimney,') as 1060°; to the second, 760°; and the third, 635°; and this, be it observed, with the consumption of only 3 cwt. of coal to each experiment. I should like Professor Fisher to give us the temperature of the waste heat in the chimney of a furnace burning from 20 to 30 tons of coal per day. We know the current is so strong that it often carries up small coal and cinders along with it: that the heated gases often take fire by a spark from the furnace, and burn at the top of the funnel with a fierceness almost equalling the flame from a blast furnace. Is this flame or waste heat employed in creating steam? and how much is the coal utilized? If we place the figures thus—petroleum = 1·4, coal = 0·4, it would very likely be too much in favour of the coal. We shall never fully learn the wicked waste we are now making of this valuable fuel until petroleum supersedes it, which it certainly will do within a few years."

38. *Peat as a Steam Fuel.*—The enormous supply of peat in various districts of this country (see end of par. 40) and in other parts of the world, has naturally attracted the attention of scientific men, with a view to economize it as a fuel. The following article from the "Scientific American"—of date April 29th 1865—followed by the article from the "Mechanics' Magazine" which it refers to, will place the leading features of the question before the reader. "In another part of this issue we have given extracts from the London *Mechanics' Magazine,* concerning some interesting experiments made with peat as fuel for steam engines —locomotives in particular.

"From the article it appears that the most extraordinary results were obtained with peat when deprived of its moisture, and condensed by a machine specially designed for the purpose. It may be that in peat we shall find an economical substitute for coal; at its present prices, and even at rates much below, for the marketing of the former substance or preparation of it so as to render it available must certainly cost far less than for coal. No shafts have to be sunk, no extensive and costly system of engineering and surveying are needed, and beyond the expense of the machinery for condensing it, or getting the water out of it by mechanical processes, little seems to be required to utilize the deposit with which nature has covered large tracts of land in this country.

"The Chicago *Tribune* thus speaks of a sample of peat which it has received from parties owning one bed which is estimated to contain 250,000 cords:—

"'This peat, in colour, resembles the outside of pressed tobacco that has been exposed to light and air, and is quite as hard and heavy. The internal structure is so compact that on cutting it with a knife a smooth polished surface is formed. The specimens that we have burn with a flame clear and brilliant as seasoned maple or hickory, and produce no unpleasant odour like coal. Specimens of the peat have been exhibited to Dr. A. A. Hayes, of Boston, analytical chemist; Dr. E. Carr, Professor of Chemistry in the Wisconsin State University, and other distinguished practical men, and they speak highly of its merits. Professor Hayes says, 'its flaming quality is of a marked character,' and that 'the inflammable part has a high heating power, and burns freely and clearly from the ash. Take the 59 parts of the inflammable compounds, as representing the positive combustible matter of this peat, we have an equivalent closely corresponding to that of oak wood; and I am led by my results to expect an equal heating power from an equal weight of this peat, burned in comparison with wood.' In regard to its gas-making powers, Prof. Hayes says, 'it exceeds all common cannels, and of course is far above any bituminous coal, and can be worked with *poor* coal to make *good* gas. There are only two or three cannel coals known which afford so much illuminating material, placing this peat in the first class of gas materials.'

"In former numbers of the *Scientific American* much has been said regarding this substance, and one of our large iron workers having tried it was not impressed with its great utility; but where such striking results as that recorded in the *Mechanics' Magazine* are obtained, and the testimony of scientific men is freely given as to its value, it would seem that further experiment here would be likely to establish its character as a cheap *and valuable fuel.*"

The following is the article in the Mechanics' Magazine alluded to in the above. "The value of peat, when properly dried, is well-known and admitted both for domestic fuel and for generating steam; and charcoal properly made from such peat is in all respects, equal, if not superior to wood charcoal. When dug from the bog, peat generally contains from fifty to seventy-five per cent. of water. The difficulty of getting rid of so much moisture has led to a preference for the upper portions of the deposit, which abound most with roots and coarse fibres, and part most readily with the water not actually shut up within those fibres. But this produces an inferior fuel which will not stand the blast nor make a good charcoal. The inference drawn from practical experience is, that to insure commercial success in utilizing peat, the operation must be inexpensive and expeditious, costly machinery being avoided. To produce a perfect fuel the coarse roots must be removed and the smaller fibres broken up. These objects appear to be accomplished by a simple machine, the invention of Mr. Buckland (see next par.), which was to be seen in operation at the International Exhibition, 1862. The fuel prepared by this process is called condensed peat, in contradistinction to compressed peat. From four to five tons of peat as taken from the bog are required to make one ton of dry condensed peat. The cost varies in different localities, but it may be safely assumed that the average cost will not exceed that of coal at the pit's mouth. Peat thus prepared burns very freely, will stand a powerful blast, emits great heat, is smokeless, and produces less ash than the average of coal or coke. It is impervious to water, improves by keeping, and is incapable of self-ignition. From two and a half to three tons of prepared peat will make one ton of excellent charcoal, according to the degree of carbonization required.

"The general heating power of the condensed peat has been proved to be very superior to that of coal; and, in fact, this article appears to be well adapted as a fuel for steam engines, whether marine, stationary, or locomotive. Its use has been found to effect a saving of fifty per cent. in time in generating steam, and it will do double duty as compared with coal. The absence of smoke and clinkers, and the preservation of furnace *bars and boilers* from the destructive effects of sulphur from coal, are additional and important advantages. The peat has been tried on board a river steamer with perfect success. The vessel was under steam 2 h. 20 min., during which time the total quantity consumed was 12 cwt., the average consumption of coal for a similar trip being 12 cwt. per hour. It should be observed that the full effect of the fuel was not here obtained, as the fire-bars, being of the ordinary description, were too wide apart for peat, consequently a portion fell through only partially consumed.

"The locomotive engineers of these railways in Ireland united to carry out a practical trial of the condensed peat, on the Belfast and Northern Counties Railway, with the view of testing its qualities as a fuel for locomotives. The trip was made from Carrick junction to Ballymena, a distance of twenty-seven miles. During the whole of the journey there was an excess of steam, although the fire-door was kept continually open, and the damper down, for the greater portion of the distance. The pressure at starting was 100 lbs. per square inch. The commencement of the journey was up an incline of 1 in 80, four miles long, and with double curves; while ascending the incline the pressure rose to 110 lbs., and afterwards to 120 lbs., and this with the fire-door open. The speed was about 40 miles per hour. While on the way the fuel emitted no smoke, and very little when at stations. The fire-box was examined at Ballymena, and a very small portion of clinker was found. The smoke-box was perfectly free from cinders or dust—a proof that the fuel had stood the blast exceedingly well; and it is the recorded opinion of the experimenters that the condensed peat was in every respect well adapted as a fuel for locomotive purposes."

39. *The Manufacture of Condensed Peat.*—The process of making the condensed peat which is referred to in the last par., and which is patented by Mr. Buckland, is thus described by Mr. P. Nursey in his paper on "Fuel" already alluded to. "The process of manufacture is as follows:—Immediately the peat is dug from the bog it is thrown or tipped into a hopper, beneath which is a strainer formed of perforated metal, and within the strainer is an Archimedean screw. At the bottom of the strainer is a small opening through which any very coarse undecomposed roots and fibres which will not pass through the perforations of the strainer fall into a waste pipe and are rejected, or may be

used for any purpose not requiring superior fuel. By turning the screw within the strainer the small fibres are cut up by the sharp edges of the perforated metal, through which they pass with the decomposed part of the peat with which they thus become assimilated. A strainer of two feet in diameter, with perforation of one-eighth of an inch diameter, and fifteen to the square inch, contains about 12,000 holes, which are equal to an aggregate aperture of a square foot. A strainer of this size will discharge about eight tons of peat per hour, or nearly one hundred tons in twelve hours. The decomposed peat protrudes through every hole in the strainer, and drops, in vermicular forms, upon an endless band which delivers the strained peat into a brick machine which will mould in any suitable shape or size. The operation of moulding the peat into one of Clayton's small brick machines was to be seen in the International Exhibition. The strainer being enclosed in a heated chamber, with an opening for the escape of steam, the moisture is rapidly driven off from the worm-like strings as they fall upon the band, giving solidity to the mould blocks of peat as they pass through the die of the brick machine, and their being then at high temperature expedites the subsequent process of drying. Very little power is required for the whole operation, which is performed continually and with great rapidity. The moulded blocks of peat are removed to a drying shed through which a current of hot moist air passes, and they soon, without compression, become as hard as oak, and more dense than any peat submitted to hydraulic pressure, the specific gravity being from 1·15 to 1·50, and that of highly compressed peat 1·08. From four to five tons of wet peat, as taken from the bog, are required to make one ton of dry condensive peat, the total cost of which necessarily varies in different localities, but it may be safely assumed that the average cost will not exceed that of coal at the pit's mouth. Peat thus prepared burns very freely, will stand a powerful blast, emits great heat, is smokeless, and produces less ash than the average of coal or coke. It is impervious to water, improves by keeping, and is incapable of self-ignition. From two and a half to three tons of prepared peat will make one ton of excellent charcoal according to the degree of carbonization required, the cost of which would be about 10s. per ton; but in converting the peat into charcoal, 1 cwt. of hydro-carbon, or peat tar, may be drawn from one ton of peat, the value of which, for illuminating and lubricating purposes, will greatly reduce, if not entirely cover the cost of the charcoal.

"The general heating power of the condensed peat is very superior to that of coal. The following is a tabulated statement of some experiments made by Messrs. Jackson and Townson, with the view of ascertaining the comparative boiling, evaporating, and fusing properties of condensed peat and coal. Five samples of peat and one of coal were tried, the same quality of each in weight being used :—

Fuel.	Time in which the same body of water was brought to the boiling point.	Time in which the same body of water was evaporated.	Time in which the complete fusion was effected.
Coal (good furnace),	6 minutes.	14 minutes.	31 minutes.
Peat, No. 1.	1½ ,,	6 ,,	14 ,,
,, ,, 2.	1 ,,	7 ,,	17 ,,
,, ,, 3.	1 ,,	7 ,,	26 ,,
,, ,, 4.	1 ,,	6 ,,	17½ ,,
,, ,, 5.	1 ,,	5 ,,	11 ,,

"It will be observed that No. 5 possesses a remarkable degree of heating power: its durability is also much greater than that of the other four samples. All the samples were produced from the same bog, and were of fair average quality, but had been submitted to different degrees of heat in drying, so that the difference in their results was due to the mode of treatment and not to any difference in the quality of the peat. The duration of the fuel, after ignition, was the same with the coal as with an equal weight of the No. 5 sample of peat. The duration of the other samples of peat was one-third less than that of the coal.

"The condensed peat appears very well adapted for steam engines, whether marine, stationary, or locomotive, inasmuch as its use has been found to effect a saving of fifty per cent. in time in generating steam, and it will do double duty as compared with coal. The absence of smoke and of clinkers, and the preservation of fire bars and boilers from the destructive effects of the sulphur in coal, are additional and important advantages. In a trial trip, made by Mr. Fothergill, with a river boat using the condensed peat, the vessel was under steam 2 h. 20 min., during which time the total quantity consumed was exactly 12 cwt. The average consumption of coals for a similar trip was 12 cwt. per hour. In this instance the fire bars, being of the ordinary description, were too wide apart for peat, and thus the full effect of the fuel was not obtained, as some portion passed through only partially consumed. There was no smoke, nor was there any deposit of clinker on the fire bars—two valuable properties."

40. *On Torbite—a new Preparation of Peat—and its uses.*—From a paper under this title, read by Mr. D. K. Clark, C. E., before the British Association, we take the following extracts.

"According to the system matured and established at Horwich the peat, as it comes from the bog, is thrown into a mill expressly constructed, by which it is reduced to a homogeneous pulpy consistency. The pulp is conveyed, by means of an endless band, to the moulding machine, in which, while it travels, it is formed into a slab, and cut into blocks of any required size. The blocks are delivered by a self-acting process on a band, which conveys them into the drying chamber, through which they travel forwards and backwards on a series of endless bands at a fixed rate of speed, exposed all the time to the action of a current of heated air. The travelling bands are so arranged that the blocks of peat are delivered from one to the other consecutively, and are by the same movement turned over in order to expose fresh surfaces at regular intervals to the action of the drying currents, so that they emerge from the chamber dry, hard, and dense. To the peat substance thus treated the name of 'torbite' has been given, from the Latin *torbo*, by which name peat is constantly mentioned in ancient charters.

"The next stage in the process is the treatment of the torbite in close ovens, when it may either be converted into charcoal for smelting purposes, or may be only partially charred for use as fuel for generating steam, or in the puddling furnace.

"The whole of the Horwich system has been planned with a view to the utmost economy of time and labour. The raw peat is nearly altogether automatically treated by steam power—introduced at one end it issues from the other in the form of charcoal, within twenty-four hours after it is excavated from the bog, and the manual labour expended is almost entirely limited to the first operation of digging, consequently the actual outlay in labour and fuel in the production of the charcoal does not exceed from 10s. to 12s. per ton; but, in addition to the economy thus effected by charring, in close ovens, a considerable quantity of valuable chemical products are yielded, as ammonia, acetic acid, pyroxylic spirit, paraffin oils, the sale of which alone will nearly cover the expenses of the whole process.

"The fatty matter separated by distillation forms an excellent lubricating grease, the yield of which averages about 5 per cent. of the weight of charcoal produced; in its crude state it has been sold for £12 per ton at Horwich.

"The charcoal made from torbite is extremely dense and pure; its heating and resisting powers have been amply and severely tested, and with the most satisfactory results. At the Horwich works pig iron has been readily melted in a cupola. About 80 tons of superior iron have been made with it in a small blast furnace measuring only 6 ft. in the boshes, and about 26 ft. high. The ore smelted was partly red hematite and partly Staffordshire, and the quantity of charcoal consumed was 1 ton 11 cwt. to the ton of iron made, but in a larger and better constructed furnace considerably less charcoal will be required. It has also been tried in puddling and air furnaces with equally good results, considerably improving the quality of the iron melted. For this purpose the fuel was only partially charred, in order not to deprive it of its flame, which is considerably longer than that from coal. Some of the pig iron made at Horwich was then converted into bars, which were afterwards bent completely double when cold without exhibiting a single flaw. Messrs. Brown and Lennox, in testing this iron for chain cables, have reported that its strength was proved to be considerably above the average strength of the best brands.

"In Germany peat mixed with wood charcoal is very extensively used in the production of iron, the peat as prepared there not being sufficiently solid to do the work alone, but it is found that the greater the proportion of peat that can be used the better is the quality of the iron produced. The gas delivered from the high furnaces has also been satisfactorily employed in the refining of iron and the puddling of steel. The value of peat in the production of iron has long been established. Iron metallurgists are agreed in the opinion that iron so produced is of very superior quality. In every stage of iron manufacture, and in welding, peat charcoal is most valuable. At Messrs. Hick and Son's forge, in Bolton, a large mass of iron, about 10 in. square, was heated to a welding heat with peat charcoal made at Horwich. The time occupied was less than the operation would have taken with coal; the whole mass was equally heated through without the slightest trace of burning on the outside, and in hammering out the mass as much was done with one heating as ordinarily required two heatings to effect.

"The importance of obtaining an abundant supply, at cheap rates, of peat charcoal, cannot, therefore, be too highly estimated.

"For the generation of steam the fuel made at Horwich has also been well tested, and its superiority over coal practically demonstrated both in locomotives and stationary engines. On the Northern Counties Railway of Ireland a train was driven with it from Belfast to Portrush, a distance of seventy miles. The result at the end of the journey showed a saving, as regards weight consumed, of 25 to 30 per cent. over the average of three months working with coal on the same journey. There was an excess of steam throughout the run, though the fire-door was constantly open and the damper down. At starting the pressure was 100 lb., but during the trip, and while ascending a steep incline, it rose to 110 lb., and afterwards to 120 lb. with the fire-door open. While running there was no smoke, and very little when standing still.

"At the Horwich works the fuel was tested against coal under the boiler there. This was done on two consecutive days, the fire having on each occasion been raked out the night previous.

"The following results were obtained :—Coal got up steam to 10 lb. pressure in 2 hours 25 minutes, and to 25 lb. pressure in 3 hours; peat fuel got up steam to 10 lb. in 1 hour 10 minutes, and to 25 lb. in 1 hour 32 minutes; 21 cwt. of coal maintained steam at 30 lb. pressure for 9¾ hours; 11¼ cwt. of peat fuel maintained steam at the same pressure for 8 hours.

"But in addition to this a large economy is effected by the use *of peat fuel for* the generation of steam in the saving of boilers and fire-bars from the destruction caused by the sulphur in coal, from which peat is free. In Bavaria peat fuel has been used on the railways for several years past, and the economy effected by its use in the wear and tear of the engines is stated by the officials in their reports to be very considerable.

"The bogs of Great Britain and Ireland cover an area exceeding five millions of acres, the average depth of which may be taken at 20 ft. Nature has thus supplied us with the means of adding to our stock of fuel some twenty thousand millions of tons.

"In Ireland about a million and a half of acres have been thoroughly surveyed. In the reports of these surveys it is stated that beneath the peat an excellent soil, well situated for drainage, was found fit for arable or pasture land. When it is considered what peat is capable of doing, and all the results involved in the question of utilizing peat, it is impossible not to feel impressed with the conviction that in what has been accomplished at Horwich the foundation has been laid of an undertaking of great national importance and interest."

41. *Artificial Fuel.*—From the vast quantities of refuse and other material which result from our coal-working operations, it has long been a point of importance to have some means of utilizing them. In referring to the various modes in use to effect this, Mr. Nursery—in his paper on fuel read before the Society of Engineers, and from which we have already quoted—thus remarks: "Very few have proved commercially successful, or even practically adaptable to the necessities of steam engineering. Of the few that have succeeded, three only appear to have attracted particular attention by their merits. These are respectively Warlich's, Wylam's, and Bell's patent fuels, and they occupy very good positions in the tables of results of Sir H. de la Beche and Dr. Lyon Playfair's experiments previously noticed. With regard to their commercial position, Warlich's would seem to have maintained the supremacy; information respecting the other two is scant and questionable.

"Warlich's patent fuel is manufactured of the best Welsh steam coal screenings, deprived of foreign matter by machinery, and then incorporated with a bituminous substance. The mixture is passed through pug mills, and pressed into square blocks

9 in. × 6 in. × 5 in., under a pressure of three tons per square inch, and are afterwards subjected to about 800 deg. of heat in retorts, by which means the noxious gases, always existing in coal, are neutralized and driven off, and the fuel rendered not only impervious to the influence of climate, but also perfectly free from all liability to spontaneous combustion.

"Among the advantages possessed by this fuel may be noticed its freedom from smell or dust. Being in square blocks it is well adapted for stowage, and, forming a compact mass, is free from the evil present in the finest Welsh coal—a large percentage of dust; in fact, all the fuel shipped is available for use at the port of discharge. Economy in space is another point. It occupies about one-third less space than ordinary coal, and from its compact and uniform character it can be stowed on deck and in other places quite unfit for the stowage of coal. Economy in consumption—a most important feature—is abundantly proved by the Government trials made at Portsmouth, and presented to the House of Commons in June 1858.

"All coal deteriorates rapidly if exposed to the weather, and in course of time becomes comparatively useless: but from its peculiar manufacture, this fuel suffers no deterioration from the injurious effects of climate. Its freedom from spontaneous combustion is consequent upon the adaptation of heat in its manufacture; there has not been an instance of spontaneous combustion during the twenty years this fuel has been in use. It effects a great saving of fire bars. Welsh coal, as is well known, is very destructive in this particular. In some experiments conducted by Dr. Lyon Playfair, at the instance of the Government, with a view of ascertaining whether the health of passengers and crews were at all imperilled by the storing of fuel on board ship, several interesting facts were eliminated. The fuel was put to severe tests and was found unobjectionable. On coking some of the fuel it produced 83·47 per cent. of coke, thus showing that it contained a larger amount of fixed carbon and less volatile matter than ordinary coal. The amount of ash was 5·67 per cent.

"This fuel is very largely used on foreign railways, both on the Continent and farther abroad, there being depots in several parts *of the world.* Works for its production exist on an extensive scale at Swansea, where 100,000 tons are produced annually, the working time being ten hours per day; by night and day work the annual yield of these works could be doubled without increasing the present staff. The usual stock is from 15,000 to 20,000 tons; a thousand tons can be loaded in ten hours, so great are the facilities the size and form of the fuel could afford in this respect. Its cost is about 12s. per ton delivered at the works, which is also the price plus freight to any other part"

SECTION SECOND—FURNACES.

42. *Coke Ovens.*—From an article in the Mechanics' Magazine, under date March 24th, 1865, we take the following extract:—"These ovens vary considerably, as well in their form as in minor constructive details. Some are circular and are used singly, or in connected groups; others are square, and built in blocks of eight or so, having a series of air passages formed in the brickwork, the ovens being connected with a central flue. But it is not so much the form of the oven, as the proper admission of air to the coking coals, which has an important influence upon the character of the produce. There is no great superiority in the results of working with the most elaborately constructed, and consequently costly ovens, over the cheaply-made circular ovens, having a well-regulated supply of air. This description of oven is circular in plan, with a domed roof having a central opening, and built of a capacity sufficient for holding a charge of about five or six tons of coal. A necessary amount of air is admitted by openings left at the top of the doorway, which is built up with brick, and the air holes are finally closed as required and luted with clay. The brick-built door is taken down when the process of coking is completed, and water is injected to cool down the coke, which is forthwith removed by a shovel suspended from a crane, and the oven is then ready to receive another charge of coal. Messrs. Cory use ovens of this description erected in a group and connected with a central flue. In Church's circular ovens, which are upon the same general plan, a series of air passages are formed beneath the coke bed, and out of contact with the coke. These passages are opened on the completion of the coking process, and a current of cold air is thereby admitted

which assists in cooling down the hot coke, no water being used for this purpose. The effect of this is the production of a perfectly dry coke, free from all moisture, until absorbed from the atmosphere. Coke thus made was for a time held in considerable repute for its steaming power. But the plan of cooling with water is now generally preferred, and for the reason that when the coke is drawn out hot and cooled outside the oven a great quantity of small coke results, whilst when cooled with water inside the oven there is a better return of large coke.

"An improved form of oven, in which both coke and gas can be made at the same time, was patented a few years since by Mr. Cox. The arrangement consists of an oven having a return flue over it, and over this again is a gas retort, the ovens being built in a row, and communicating with a central chimney. In the brick piers which separate the ovens, passages are left, which open into the back of the oven, and through which air is admitted; the air thus becomes heated before reaching the coking coal, over which it passes to the front of the oven and thence through the return flue under the gas retort to the chimney. The retort is acted on by the escaping heat of the oven, but for coking only the chimney might be placed at the front of the oven, and the cost of erection be thereby diminished, without the quality of the coke being impaired. An iron frame or cradle is placed on the floor of the oven upon which the coke is drawn out hot and then cooled with water, but this plan involves a larger quantity of small coke than by cooling in the oven, the coke being more friable when hot. The coke ovens of the Bristol and Exeter Railway at Bridgewater are a good example of an efficient arrangement; they embrace modifications of both Cox's and Church's patent ovens. A series of cooling air passages beneath the coke bed, as in Church's oven, are made to come in contact with the coke to promote equal ignition, and the side air passages have frequent openings into the oven. There are also upper passages for the further regulation of the admission of air. These ovens are built in blocks of eight, two rows of four being placed back to back, and communicating with a central chimney. The lower sets of air passages are left open for a short time to promote the equal ignition of the whole mass of coal at once, and when this has taken place they are closed. By the upper passages the supply of air to the burning fuel is regulated, and by the side openings the air is distributed above the burning mass as equally as possible. The yield of these ovens is about 13 cwts. of good coke, 6½ cwts. of small and waste coke, from a ton of Cardiff coal; besides this there are some ashes fit for lime-burning. The increase in the comparative quantity of small to large coke is probably consequent upon the use of cradles similar to that employed in Cox's ovens, upon which the coke is drawn out hot, which method of cooling, as already noticed, tends to increase the quantity of small coke.

"In all these ovens the process of coke-making is carried on in a similar manner. They are charged with their respective quantities of coal in such rotation as to produce the necessary supply of coke each day. When the plan of drawing the coke hot and cooling it outside the oven is adopted, the fresh charge of coal is readily ignited by the heat of the oven, but when the coke is cooled inside the fresh coal requires to be lighted. After each fresh charge the door is lined inside with fire-bricks and made air tight with a fire-clay luting. In some cases, as in the circular ovens, no door is used, but the opening is built up with fire-bricks, openings being left for the admission of air, such openings being closed as coking progresses. The process of coking occupies from forty-eight to ninety-six hours, the variableness of duration being the result of several circumstances, such, for instance, as the composition of the coals, the class of oven employed, and also atmospheric conditions. A much longer time is occupied in the process when the coal contains but little sulphur, although an excess of sulphur is injurious to coke. Where an excess has been found electricity has sometimes been employed to remove it before the coke was drawn. But a certain amount of sulphur promotes combustion, and, in this respect, the Rhonda Valley coal of South Wales makes a better coke than the Newport coals, which contain a greater amount of sulphur and are better suited for household purposes. In making coke the progress of combustion has to be observed, and the admission of air regulated accordingly. When flame ceases to issue from the heated mass of fuel the supply of air is shut off, and this is done some time previously to the coke being cooled. It is the duty of the coke-burner to regulate the admission of air and to watch the progress of combustion by eye-holes left for that purpose. Much depends upon his care and skill, and therefore, with a judicious exercise of care, the cheaper class of ovens are, for all practical purposes, as efficient as the most expensive."

43. *Siemen's Regenerative Gas Furnaces and Producers.*—The following is an abstract, given in "London Journal of Arts," of a paper read before the British Association by Mr. S. N. F. Cox, descriptive of this important invention. "The paper opened by stating that the system of regenerative gas furnaces having now been before the manufacturing world for several years, and employed for the manufacture of glass of all kinds, of iron and steel, and nearly every other article in the production of which great heat was employed, and having proved in nearly every case successful, it had ceased to be an experimental system, and had become an established and recognised success. The paper then described, by the aid of diagrams, the construction of the furnace in which the gas was burnt, and the gas producer for all descriptions of fuel, except binding coal, the method adopted for making the gas, and then the binding coal producer, and the nature of the fuel. By the process, a flame was obtained (equal to a white heat) which contained nothing that could injuriously affect the most delicate manufacture, for even sulphuring was prevented; for the sulphur in separating from its hydrogen took up oxygen supplied by the carbonic acid and water, forming sulphurous acid, a firm compound, which was not decomposed on meeting metallic oxides in the furnace. The nature and intensity of the flame was also under the instant control of the man in charge of the furnace, so that the chemical nature of the flame could be altered at will—one minute an oxidising flame being obtained, and the next a reducing or carbonising one. So also the amount of the flame could be altered from the smallest flicker to the complete filling of the chamber with an intense body of flame. The paper pointed out the immense advantage thus obtained in furnaces where the delicate operation of heating or melting steel was carried on; and hence a great number of influential firms were now adopting the furnaces in England for re-heating purposes, especially for reheating steel blooms and ingots. The paper contained statements from firms using the furnace, stating the favourable results of their experiments. It pointed out that

the advantages of the system were, first, an immense saving of fuel. A ton of steel by the furnace was melted with an average weight of a ton of coal, instead of two and a half to three tons of coke, which represented six to seven tons of best coal. With such names before them as Meyer, Borsig, and Krupp, as employers of Siemen's furnaces for steel melting, it did little credit to our English enterprise to say that there was hardly one furnace in England in constant work for steel melting. Besides the saving of fuel there were other advantages in the working of the furnace, such as cleanliness, no solid fuel being brought into the shop where the furnaces were, the fuel being converted into gas at any convenient distance from the furnaces; compactness of arrangement, saving of labour, and, above all, improvement in the processes themselves. In every trade in which the furnace might be employed, the same advantages were apparent; and though the furnaces were costly, and required a large outlay at first, especially in old works, they soon paid for themselves."

The following is a description, taken from the "Scientific American," of this furnace, followed by an illustration taken from the paper read by Mr. Cox above alluded to, and which appeared in the "Engineer," under date Oct. 6, 1865:—"The first object of the invention is to produce an intense heat. When solid fuel is burned in an ordinary furnace, at least 1000° of heat are absorbed and made latent by the change from the solid to the gaseous form. In Siemen's furnace this change is effected before the fuel is introduced into the heating chamber. This is done by setting a mass of coal on fire in a close chamber, and subjecting it to slow combustion with an imperfect supply of air. In this operation a large portion of the coal undergoes destructive distillation, and is converted into hydro-carbon gases and vapours of a highly combustible nature, while that portion of the coal which is burned is formed into carbonic oxide only, in itself a combustible gas. The gases thus generated are led into the heating chamber, where they are mingled with just the proper supply of atmospheric air to effect their complete combustion. The absorption of heat by the change of state, having taken place in the gas-generating chamber, the heat resulting from the combustion of gases in the heating chamber is at least 1000° greater than that which results from the burning of solid coal.

"But a considerable portion of the heat resulting from the chemical union of the gases with the oxygen of the air is absorbed in raising the temperature of these substances. Mr. Siemen, therefore, to still further augment the intensity of his heat, raises the temperature of both the atmospheric air and the gases before they are introduced into the heating chamber. This is effected by passing each through a honeycomb mass of brick-work previously raised to the temperature of white heat. There are two pairs of these masses of brick-work, and they are heated alternately by the passage through them of the products of combustion, on the exit of these products from the heating chamber.

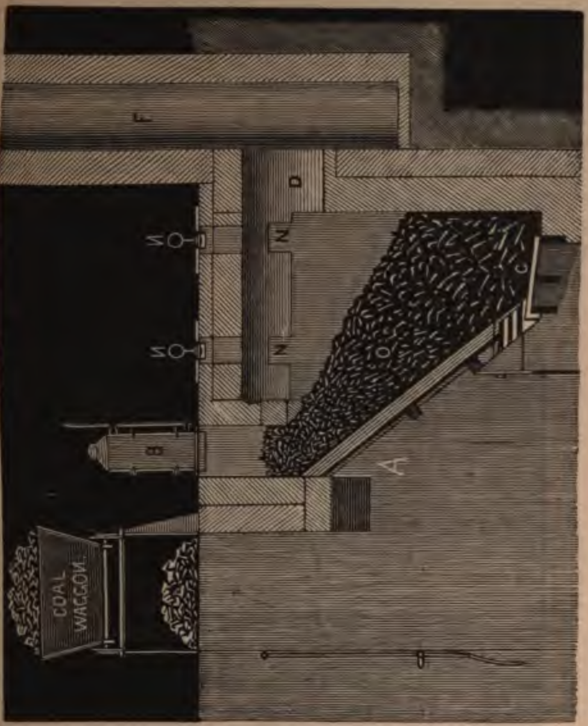
"As the supply of air and combustible gases may be readily controlled by valves in the conducting pipes, the quality of the flame may be varied at will. By adjusting the flow of gas slightly in excess of the air required to effect its combustion, the presence of free oxygen to attack the iron would be avoided, and bars might be raised to a welding heat without being burned in the least.

"From the clearness and controllability of the flame, the intensity of heat, the absence of smoke, and other advantages, this furnace is doubtless destined to play a very important part in the mechanic arts."

The following is Mr. Cox's description of the form of furnace illustrated in Fig. 13, and which is a "section of a gas producer intended for the use of all fuels except binding or caking coal. It is a chamber three sides of which are formed with brick-work, the fourth is partly a cast-iron plate A, covered with bricks to protect it from the action of the fire, and partly an open fire-grate C. This chamber is covered with a brick-work arch, through which certain openings are left, over some of which are placed cast-iron hoppers B, through which the fuel is supplied, and the remainder of the openings are only made and used for inspecting the fuel during the process of gas-making, and are opened and closed at pleasure by means of the stopper N. The gas is made by igniting, in the first place, the fuel on the grate C.

"That part of the fuel which is on the grate itself burns by the entering air into carbonic acid, and the heat evolved ignites the mass above it. The carbonic acid thus formed passes slowly *upwards through* the incandescent mass of fuel O, and becomes

Fig. 13.



converted into carbonic oxide, which passes through the remaining portion of the fuel and mingles with the volatile constituents of the coal—hydro-carbon gases, water, ammonia, and some carbonic acid, which are distilled from the coal immediately upon its entrance into the producer through the hopper B, and which are, of course, the same as would be evolved from it in an ordinary gas retort.

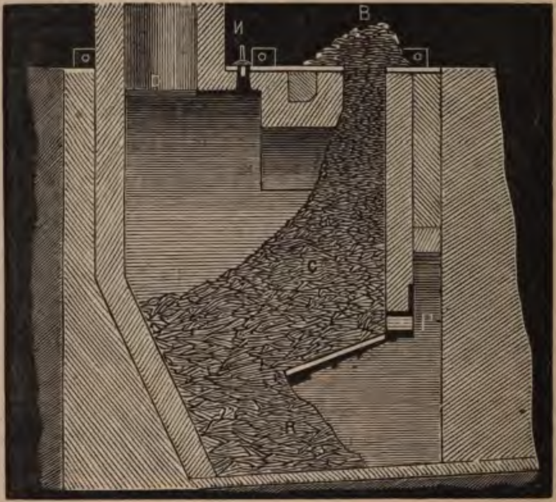
"All the combustible portions of the fuel having been thus converted into a crude gas, only the incombustible portions of the fuel remain, which are removed through the grate from time to time in the form of clinkers or dust.

"Water is also supplied below the grate, and being vaporised by the heat, is carried (by the current of air passing through the grate) into the white-hot fuel, and in its passage through the incandescent mass is decomposed and rearranged as hydrogen and carbonic acid.

"The gaseous fuel thus formed is carried from the producer, through the opening D, into an upright stack or chimney E, thence into a cooling tube, and then down through a second stack, a short distance from the producers, into an underground flue leading to the furnace.

"Fig. 14 represents a section of the form of producer used where binding or caking coal is used, and several of this form are in use at Sir W. Armstrong and Co.'s works at Elswick, at Messrs. Thomas Richardson and Son's, at Hartlepool, and on the Continent. Coal is thus used for furnace work which has been hitherto thrown aside as useless and allowed to burn to waste, or at most has only been used for making a very inferior kind of coke.

Fig. 14.



"This producer works in the same way as that last described, except that the air enters through the opening P, and the steam through the opening R, which latter opening is also used for extracting the clinkers, dust, and other incombustible material in this waste coal, or, as it is termed in the neighbourhood, 'duff.'

"The gas made in these producers has been frequently very carefully analysed at the St. Gobain Plate-glass Works in France, and the average constituents of 100 parts have been found as follows:—

Carbonic acid,	4·1
Oxygen,	0·4
Carbonic oxide,	23·7
Carburetted hydrogen,	2·2
Hydrogen,	8·0
Nitrogen,	61·5
	99·9"

SECTION THIRD.—SMOKE CONSUMPTION.

44. *History of Smoke-Consuming Contrivances.*—Under the title of "Smokeless Furnaces" the 'Mechanics' Magazine,' under date May 12th, 1865, has much interesting information, of which, under the title which heads this paragraph, we purpose giving an abstract. After referring to the nature of consumption of fuel in furnaces, and to the way in which smoke is produced, the writer proceeds to describe the furnaces which have been introduced from time to time, which have "had for their object the consumption of smoke. The invention of the first smoke-consuming furnace has generally been attributed to James Watt, and as far as relates to steam furnaces this may be so. But there is evidence that in the seventeenth century smoke-preventing apparatus was used in several French manufactories. The Transactions of the Academy of Sciences for 1699 embody some experiments made by a M. de la Hire in the same direction with apparatus invented by a French engineer of the name of Delasme, many years previously. M. Delasme is said to have exhibited a furnace for consuming its own smoke in 1685 at the fair of St. Germain. But this was only a revival of Papin's scheme for making the smoke *descend through the* fire by a draught created by means

of his centrifugal blower. The scheme is feasible, and would be found effectual if judiciously carried out in practice. But the coking of the coal, and the absence of an effectual exhauster, have hitherto been a bar to its success. Franklin introduced the system into house stoves, but several impediments have prevented it coming into use. Watt's patent is dated the 17th June, 1785, and is the last he took out; it is for 'certain newly improved methods of constructing furnaces or fireplaces for heating, boiling, or evaporating of water and other liquids which are applicable to steam engines, &c., whereby greater effects are produced from the fuel, and the smoke is in a great measure prevented or consumed.' The methods proposed for carrying out his ideas were various, and consisted in passing the smoke and gases from one fire over the bright coals in another, or in causing the products of combustion from the fresh fuel to pass through heated pipes, or amongst highly-heated fuel which had ceased to smoke, and by mixing it with fresh air under those circumstances. This plan was practically worked out by Watt, by placing the coal in a vertical conical hopper, fixed in the brickwork of the boiler behind the furnace door, a stream of air being passed through the furnace door for maintaining combustion. The fire rested on a brick arch, and the air that reached it had to pass through unconsumed coal. But this plan was relinquished on account of the concretion of the coal preventing the due admission of air. In its stead Watt adopted the plan of a dead plate between the furnace door and the fire bars, upon which the coal is first coked and then pushed back upon the bars to undergo consumption. Messrs. Boulton and Watt still adopt this plan, which, with careful firing, is very effectual in preventing smoke. An example of this system may be seen at H. M. Victualling Yard, Deptford, under a thirty horse boiler erected by Boulton and Watt. The dead plate and bars are at the same angle, and their inclination facilitates the transmission of coal. Sufficient air is found within the furnace to accomplish the combustion of the gases, which pass from the green coal over the fire, where they are consumed.

"But even as a patentee, Watt was not first in the matter. John Aysel patented an improved furnace in 1772, and in 1785 R. Cameron patented a furnace for consuming smoke. One of *the first plans* brought into use for smoke-consuming upon the principle of admitting a stream of air behind the bridge, was that patented by Mr. W. Thompson of Bow-lane, in 1796. This furnace has been subsequently patented over and over again with slight variations, but none have been very successful. The difficulty of apportioning the quantity of air admitted to the varying wants of the fire has greatly hindered their success. If the valve be regulated to supply the quantity necessary when the furnace has just been fed, it will supply too much when the smoke has passed away. But if the supply of coal is regulated by self-acting mechanism, the production of smoke becomes more uniform, and the air valve may be adjusted with some chance of success. Or even in other cases the supply might be approximately adjusted by Mr. Murray's arrangements, by which the air is supplied through a tube furnished with a throttle-valve. The valve is opened by an attachment to the furnace door, and closed by means of a vane-wheel in the mouth of the tube, and which is moved by the current of air passing through the tube into the furnace. This end was proposed to be attained in Pritchard's furnace by means of a piston descending by gravity in a cylinder of air, the piston forcing out the air through a small orifice. One of the best forms of this species of mechanism was patented by Mr. Prideaux, and has proved successful in practice. The furnace door has a number of Venetian lattice bars, through which the air enters. These bars open when the furnace door is opened, and are closed by the gradual subsidence of a piston within a small cylinder at the hinge side of the door. Inside the door, a series of plates divide and heat the air as it enters, and further, keep the door cool. In 1819, Mr. John Steel, of Dartmouth, described, before the Smoke Committee of the House of Commons, an important project—a revolving fire-grate. The grate is circular, and is fed from a hopper above it. The coal is retained upon the grate by a surrounding ledge of brick, nearly beneath which a projecting plate of iron runs in a groove of sand, to prevent the escape of air into the furnace. Motion is given to the grate by means of bevel wheels, contained in a cast-iron box, and gearing into a large wheel beneath the bars. Coal is supplied at one side of the grate, and the products of combustion escape at the other; the gases being consumed in their passage over the incandescent fuel on the other parts of the grate. The invention of this grate can hardly be said to be due to Mr. Steel, as it appears to have been patented in 1816 by Mr. W. Brunton, of Birmingham, who used feed rollers for crushing the coal on its way to the fire. The revolving grate, in an improved form, was applied by Boulton and Watt to the steam furnaces of the Bank of England.

"An ingenious method of consuming smoke consists in lighting the coal on the top, as proposed by Cutler some years ago. But the difficulty here is to introduce fresh coal beneath the burning mass, although the plan has been revived with modified arrangements. In July, 1815, William Losh, of Newcastle, patented a combination of double furnaces, fired alternately, the smoke of one furnace passing into the ashpit of the other, by an arrangement of dampers, and ascending, mixed with air, through the fire. This is one of the most effectual methods of consuming smoke; but shifting the dampers is a troublesome matter, as to withstand the heat they must be strong and heavy. An apparatus applied to many boilers in Lancashire is known as Stanley's fire feeder, by which the coal is distributed over the furnace, almost piece by piece, from a revolving fan, which is supplied from a hopper fitted with crushing rollers. The gearing is so arranged that, as the speed of the engine quickens, the effective speed of the apparatus becomes less, and the quantity of coal supplied just equals the demands of the engine for steam. Jeffrey's plan for preventing smoke consists in causing a down draught through a shaft in which a shower of water was kept constantly falling. The smoke is thus condensed and carried off. This plan requires two or more chimneys, closed at the top, and connected by a cross-flue. There are, however, many methods of destroying smoke more economical than this. Its chief value will be found in its application to copper smelting furnaces, vitriol, and such works, for condensing the insalubrious vapours; and here its use should be made compulsory. The method of obviating smoke by admitting steam into the furnace has been frequently tried. Mr. Evans took out a patent for it in 1824, and Mr. Nasmyth introduced it into the Edinburgh Gas Works many years ago, and Mr. Iveson, of Edinburgh, has since revived the plan. In locomotives, the steam jet has been successfully applied by Mr. Clark. John Chanter has been about the most indefatigable worker in the field of smoke burning; his name appears upon a perfect multitude of patents for every variety of furnace. His principle in 1834 was to gradually dry and prepare the coal in the furnace, so that the liberated gases were burnt in the hottest part. He used two grates, air being supplied to the first by means of a tube beneath it, in the centre of the furnace; but, from the frequent variation of his plans, it is difficult to assign to him any distinct or particular principle. Mr. Cheetham drew the inflammable portions of the smoke from the upper part of the flue by means of a fan, returning them to the furnace through the ashpit, mixed with air. The result of this mixture of gas and air was an occasional explosion in the ashpit, which quietly lifted the boiler from its setting. About five-and-twenty years ago, Mr. Bourne applied some contrivances for obviating smoke in vessels of the Peninsular Steam Company. His arrangement adopted in the "William Fawcett" was a double retort furnace. The furnaces were in pairs, the intervening water-space being pierced, so that the smoke from one passed through a pipe fitted at the furnace mouth into the ashpit of the other, where it was mixed with air, and ascended into the next furnace to be consumed. One furnace thus operated as a retort, while the other was acting as a furnace. In the 'Tagus,' two Venetian bridges were formed of tiles, with a vacant space between them. The tiles were heated by the passing flame, and a thin fire being kept on the bars, sufficient oxygen passed through the burning fuel for the combustion of the gases in their passage between the tiles. By this method the smoke was entirely prevented. The arrangement in the 'Liverpool' was somewhat different, and consisted in two sets of furnace bars—those next the door being made of cast-iron, and those beyond of fire-clay. The coal was coked on the first, and pushed on to the second set. A powerful draught was provided for by two exhausting fans at the base of the chimney, which drew the air from the flues through chests surrounded by feed water, and discharged it into the paddle boxes. These arrangements were found to work so well that twenty years later Mr. Bourne adopted them for maintaining the draught in some vessels for India. Very much has been said about the argand furnace of Mr. Charles Wye Williams, in which air is admitted by *numerous small orifices.* The practical efficiency of this furnace was tested at Boulton and Watts' works. An ordinary boiler was fired for four months with a certain kind of coal, the effect and consumption being noted. Williams' principle was then applied under conditions as nearly identical as they could be, and the consumption of coal proved to be nearly a pound per horse power per hour more than before the principle was applied. At the Deptford Pumping Station an apparatus is in use which was patented by Mr. R. A. Rumble. It consists of hoppers and moveable fronts having inclined planes of peculiar construction attached to them, on which the fuel falls and is pushed gradually forward. No smoke is seen, and clinkers are to a great extent prevented. The apparatus is self-acting, and applicable to marine as well as to stationary boilers."

45. *Smoke Burning in Manufacturing Furnaces.*—Under the above title, the 'Engineer,' of date Sept. 22d, 1865, has the following amongst other remarks: "No patent covers the use of a regular and equal firing, by which the sudden development of too great quantities of cold gases is prevented. The use of Welsh coal, so generally employed in London for avoiding smoke, is only an indolent substitute for the proper firing of a soundly-constructed furnace. The principle of double-firing, by which the necessary irregularities of any furnace can be made to correct those of the other, could also be very generally adopted. The supplementary introduction of atmospheric air into the products of combustion is yet another means of command over the necessary irregularities in the combustion of any furnace. The designer can often vary the application of the principle by either admitting air in an intermittent way through the fire-door, or by letting it into the already-formed volume of burning gases.

"It is notorious that, notwithstanding the complaints yet occasionally heard, the amount of smoke in the atmosphere of London has been considerably reduced within the last ten years by means of the Metropolitan Smoke Nuisance Abatement Act. The necessary penalties have not merely had an effect on the steam furnaces of the vessels plying on the river 'above bridge,' but also on the large furnaces used in the different metropolitan manufactories, such as the Lambeth Potteries. Much, no doubt, yet remains to be done, but London, compared with what it was ten *years ago,* affords visible evidence that where there is a will there is a way of consuming the smoke of large furnaces. In other large cities, in which only the provisions of the Local Government Act can be enforced against smoke, the improvement is not so manifest—from the simple fact that the necessity is not so pressing. The stringency with which the clause of this Act against smoke is enforced naturally varies with local circumstances. It has indeed happened that a local magistrate sitting on the bench has had a summons for not burning smoke brought before him against himself; but we do not think that it is in human nature that such a case could be often repeated. A very successful plan of furnace for potteries was first introduced into the works of Messrs. Henry Doulton and Watts, of Lambeth, about six or seven years ago. Its general adoption has almost cleared Lambeth of the thick volumes of smoke that used to enshroud the numerous potteries in that part of London. The fifteen large furnaces of the Messrs. Doulton are each furnished with ten grates, upon which is burnt a very bituminous north-country coal. The furnaces are fired from above, and just beyond the opening where the fuel is introduced, on the arch of each grate, is a vertical division of perforated bricks. The amount of the air passing through these holes can be increased or diminished at will. In its passage through the holes it gets heated, and mingles behind the bridge with the gases of the coal, entering into a combustion which is complete in the interior of the furnace. No visible smoke is formed, but it appears if the passages through the perforated bricks are temporarily closed.

"In spite, again, of the enormous volumes of smoke which are being continually belched forth from the numerous puddling furnaces throughout the kingdom, we think they could often be constructed to burn their own smoke, even without the aid of Mr. C. W. Siemens. (See par. 43).

"In the works, for instance, of Messrs. Johnson Brothers, of Bradford, are what are probably unique specimens of very successful smoke-consuming puddling furnaces. The plan adopted is very simple. The furnaces are arranged in couples, each pair heating a vertical boiler, but each furnace being in other respects independent of the other, in order not to interfere with the puddling. Their gases only combine under the boiler, when they are conducted to a central chimney serving for the whole shed.

In other respects the furnaces do not differ from the common puddling furnace, except in being rather shorter than ordinarily. The only distinguishing feature is an opening of about the size of a brick, made in the outlet pipe, at about 18 in. from the end of the furnace. The fireman varies the area of this opening by means of a moveable brick, so that additional air is introduced, which keeps up an intense combustion in the passage, even before the gases of the two furnaces get mixed under the boiler. This simple arrangement merely embodying the principle of double firing, and of the admission of cold air into the gaseous current of the products of combustion, prevented the formation of smoke with the use of the ordinary Lancashire fuel."

46. *Smoke-burning Locomotives.*—Under the above title, the Mechanics' Magazine, April 28th, 1865, has some very valuable and interesting remarks on a subject which is now attracting considerable attention, from which we take the following extracts: "Among the first attempts to render coal-burning locomotives also smoke-burning, was that of Mr. Gray, who at a very early period introduced in the 'Lever' engine double furnaces, one above another, for burning smoke. The upper furnace had tubular fire-bars, and the smoke from the lower furnace ascended through the upper, by which it was consumed. In Dewrance's locomotive boiler the fire-box is divided in the direction of its height by an oblique partition perforated with short tubes. He thus forms a combustion chamber for mixing the gases evolved by the fuel on the grate, with the atmospheric air mingled with them, and combination thus takes place before the smoke enters the tubes of the boiler. Andrews divides the lower from the upper part of the fire-box by a partition perforated by short pipes. The upper portion thus constitutes a combustion chamber to which air is admitted by suitable orifices for the combustion of the inflammable parts of the smoke. In the arrangement effected by Healy, the boiler is a square hollow vessel, having the grate in the interior, to which the fuel is supplied through a hole at the top. On its way to the chimney the smoke is made to pass beneath a fireclay block, which dips into the fire, and thus compels the smoke to pass through the incandescent embers. A stream of air is let in at this point by suitable orifices, meeting which the smoke is consumed. M. Dumery, of Paris, has a

smoke-burning locomotive in which the coal is raised up into the fire-box by means of vanes which revolve in a case at each end of the grate. Gryll's idea is to remove the tube-plate some distance back from the fire, thus withdrawing it from the intense heat of the furnace and at the same time leaving a combustion chamber between the ends of the tubes and the fire-box. M'Connell uses tubular stays having valves, by means of which he admits air to the furnace to burn the unconsumed gases in locomotives. He also heats the feed-water by conducting it through a coil of pipe which surrounds the blast pipe in the smoke-box. This arrangement was tried on the North Western Railway, and it appears from an experiment made by Messrs. Woods and Marshall, that 1 lb. of coke evaporated 8·65 lbs of water; and a pound of coal, with M'Connell's smoke-burning engine, 5·83 lbs. They found the evaporative power of coke to be 20 per cent. greater than that of coal in the stationary engine at the station. We shall refer again to the performances of engines with M'Connell's adaptations, as against other systems. In Beattie's locomotive both a coal and a coke fire were at first employed, the coke fire consuming the smoke from the coal. But this plan was subsequently modified, a coal fire only being used, the smoke from which is caused to come in contact with a curved fire-tile bridge. This bridge deflects the smoke downwards on the fire, and forms in effect a combustion chamber, there are likewise fire-tile pipes or perforations, which being highly heated consume the smoke as it passes through them. Mr. Beattie also heats the feed water by injecting it into a vessel filled with waste steam. Longridge and Richardson's plan is to introduce the coal first upon a series of small bars near the mouth of the furnace, and when coked sufficiently there, to force it back upon the fire. On the Northern Railway of France a grate resembling a flight of stairs has been used, each bar, which is wide and shallow, forming the tread of the step. The air finds its way in through the spaces between the treads. The steps descend from the fire-door; the coal being fed on the top, is pushed or gradually falls down the declivity as it burns. These plans sufficiently illustrate the general methods by which it has been sought to alleviate the evils arising from the use of coal in locomotives. . . . The constantly varying conditions presented by the furnace of a locomotive when working create difficulties and impede the perfect action of most of the ordinary plans in use. With a view to overcome the various objections and difficulties that were constantly arising, D. K. Clark patented an arrangement whereby the volume, range, and power of the air currents are extended, and they are better adjusted to the requirements of the furnace. In this system small jets of steam are employed in aiding the thorough admixture of the air within the box. The arrangement consists in forming openings in the sides of furnaces in free communication with the atmosphere for the admission of air. Jets of steam are projected through these openings in order to draw the air into the furnace, and to diffuse and mix the air with the combustible gases as they are generated, and so to burn them and economise fuel. When the steam-inducted air-columns are directed upon the fuel it raises it to a state of intense ignition. Thus smoke is prevented and a considerable portion of the solid fuel is consumed by the inducted air. There is no construction within the fire-box, and consequently no destruction from exposure to intense heat, neither does it in any way interfere with the fire-box or the management of the fire, and is governed simply by a steam-cock near the driver. The steam nozzles here bear a similar relation to the air to which they are directed as do the blast pipes to the chimneys; indeed, they may be described as so many blast-pipes and chimneys on a very small scale turned into the fire-box, possessing in a relative degree the power of urging the draught. The various currents of air by direction of the steam are delivered with such correctness and force as to range over the entire surface of the burning mass in the furnace. The air is thus forcibly mixed and distributed amongst the gases, and the result is a perfect prevention of smoke. It is found in practice that the jets are not required to be kept constantly in use, their occasional action being quite sufficient to ensure all the benefits derivable from the application of the system when the engine is at work. They are chiefly called into requisition when the fire has just been coaled, or when steam is shut off at stations, in which cases, and especially the latter, were it not for these steam-inducted air currents, smoke must inevitably be formed and escape from the chimney. As the heat in the fire-box becomes modified in intensity, the jets may be turned partially off, and when the engine is on her way again their action may be altogether dispensed with. If the areas of the air-holes are properly proportioned, they require no regulators, that is, if they are not made too large so as to admit an excess of air."

47. *Smoke Prevention at Sea.*—From an article on this subject in the 'Engineer,' August 11th, 1865, we take the following extract:—"Straightforward, unmitigated, *non*-consumption of smoke must be sought for at sea. It is not nearly so easy to find it on land. To all appearance this thing ought not to be. The marine engineer has as much—if not more—space at his disposal as the designer of locomotives; and we are led perforce to believe, either that marine engineers and steam shipping owners are very ignorant of what is good for them, or that some special difficulties attend upon the burning of coal at sea which are not present in the same degree on shore. The first idea involves some truth, perhaps, but mixed up with too great an amount of absurdity to render it worthy of much credence. Our great firms are too well aware of the advantages to be derived from securing perfect combustion to wholly ignore the whole subject, and act without very sufficient reasons as though coal never smoked. To what then are we to attribute the fact that smoke-preventing contrivances find less favour at sea than they do on shore? We fancy that the principal cause must be found in the fact that marine boilers are usually overworked, and that as a result the system of firing adopted renders it absolutely out of the question to hope for much benefit from any device the success of which depends on the fires being left to themselves for moderate periods. It will, no doubt, be urged by the advocates of smoke prevention that a direct economy of fuel follows on complete combustion, and that the evaporative efficiency of boilers is directly increased in the same, or nearly the same, proportion. The first statement contains a great deal of truth—truth, be it observed, which works out in practice. The second statement is also true, but only under exceptional circumstances. We have been at the trouble ere now to investigate cases where smoke-burning apparatus had been applied to marine boilers which previously smoked heavily; in nearly every instance the result was that the admission of air above the fuel reduced the rate of consumption per foot of grate per hour, *and the efficiency of the* boiler was thereby diminished.

Part of the loss was made up by the combustion of the gases, but not the whole loss. The saving of fuel was commonly very marked; but, unfortunately, where the boiler was already deficient in power, the loss could not be tolerated, and the apparatus had usually to be removed. It is certain, however, that instances may and do occur in which the result of bringing about more perfect combustion is a direct increase, not only in economy, but in relative efficiency, and from such facts very magnificent deductions have been drawn ere now. In the majority of cases of the kind, however, which have come under our knowledge, we have found that a remarkable analogy exists between such high results and those given under peculiar circumstances by superheating. When a boiler is so radically bad that much water passes over to the cylinder with the steam, great advantage follows on the use of the superheater. The same apparatus applied to a good boiler may possibly give an economical result hardly worth the trouble and expense by which it is secured. In like manner, furnaces may be met with in which the combustion is so imperfect, and all the arrangements are so bad, that not only is fuel wasted, but the power of the boiler directly diminished. In such cases, of course, it is very easy to make alterations which shall at once effect a saving in fuel and increase the production of steam; but such extreme cases are rare at sea, and exceptionally rare on land.

"The principal reason, then, why marine furnaces are not smokeless or nearly so, must, we think, be found in the fact that sufficient air to secure perfect combustion of the gases cannot be admitted above the burning fuel without reducing the steam-producing power of the boilers to an extent greater than is admissible. Whether such a result follows as a matter of necessity, or of negligence or ignorance on the part of the engineer, remains open to question, and conditions vary so much that it is impossible to give anything like a satisfactory general answer. Under certain circumstances the engineer finds that, design his boilers how he will, they are forced beyond their natural capacity to an extent which renders anything like perfect combustion a physical impossibility. Argand doors are of little use to a furnace heaped with fuel within a few inches of the crown plate; possibly right up to it at the door. Again, the space available for the boiler may be so small that heavy firing is indispensable. The greatest difficulty of all in the matter is, however, the absence of sufficient draught. Locomotives smoke at stations with the blower on, because the quantity of air entering the furnace is insufficient to complete the oxidation of the gases. When running at full speed with a heavy train, the furnace is, in well-designed boilers, all but smokeless; but in the marine boiler the draught is seldom greater than in the locomotive when standing. The heat within the furnace is less, and the gases, rapidly cooled down by the boiler plates, refuse to burn. The temperature, again, of the furnace is kept down by the introduction of too much air in the wrong place. As far as regards combustion, very good results would follow in most marine boilers on a considerable reduction of grate area, the space thus lost for the admission of air being made up for by perforated doors, and, possibly, bridges. In order, however, to maintain the actual efficiency of the boilers under such conditions, it would be necessary in most cases to increase the intensity of the draught, either by the use of a fan, a longer stack, or a jet. A long stack is an evil at sea. The jet runs away with a good deal of steam, and is not quite as effectual as is desirable within chimneys of large diameter, and, therefore, it is probable that the best results would be derived from the fan—an expedient already used with very great success both in this country and in America. The principal difficulty to be contended with here, lies in the fact that the crowns of marine furnaces are usually so low that they are liable to suffer considerably from a very elevated temperature, should the circulation not be very perfect. With a more intense draught, however, the ash pits might be made shallower by lowering the grate bars, and the furnace crown protected by turning a thin arch of fire tile over the grate for its entire length. The expedient would be a little expensive, as the arch would wear out rapidly, but it would protect the gases from the cooling influence of the plates until sufficient time was allowed for their combustion, and it is not impossible that it would pay for itself by the saving effected in the repairs of the boiler.

"Although we are not disposed to believe that smokeless furnaces will *ever become the* rule at sea, still we feel convinced *that it only requires a little* energy on the part of our engineers and shipping companies to render combustion at sea far better than it is. As at present constructed too much is thought of heating surface, too little of furnace room and circulation. Smaller grates, sharper draughts, larger furnaces, and longer runs from the furnace proper to the tube plate are required; and being present, the smoke nuisance—for it is a nuisance even at sea—will be mitigated. It is not necessary that a smoke-burning device shall be employed which admits so much air that the power of the boiler is diminished. Such a scheme will never find favour at sea, even though it effected a considerable saving in fuel. The thing really in demand is a furnace which shall not only prove economical of fuel, but—which, in the eyes of the shipowner is of even more importance—will add to the efficiency of the boiler. Were it possible to produce a device by which good boilers, now working up to 200-horse power let us say, could be made to work up to 220-horse power, while each pound of coal would evaporate 8 lb. of water instead of 7 lb., the fortune of the inventor would be made. It is almost needless to remind our readers that so desirable a result cannot possibly be brought about by doors or bridges, however skilfully wrought, so long as the arrangements of the boiler itself are imperfect. Marine boiler engineering is not very far behind the age, but it is desirable that some one should step forward, break down the barriers of prejudice and routine which now invest the subject, and introduce such important, albeit moderate, changes on existing practice, as would conduce to the efficiency of our steamships and the profit of their owners."

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DIVISION THIRD.

STEAM ENGINES.

SECTION FIRST.—STATIONARY ENGINES.

48a. *Cornish Pumping Engines.*—In p. 119, par. 26, the of volume of "Engineering Facts and Figures for 1864" some remarks on the high position which the Cornish pumping engine has for long maintained in mechanical engineering, and also as to the opinion now gaining ground amongst many authorities that it, in some points at least, scarcely deserves this position. It is probable, however, that this deterioration, as pointed out in a recent article in the "Mining Journal," arises from want of care and proper attention. "In the year 1811," says this article, "Mr. Joel Lean began to report the performances of the Cornish engines, and during that year, it is said, issued his first engine report. In the year 1827 an eminent engineer, Capt. Samuel Grose, commenced to improve the duty of steam engines at Great Wheel Towan. It is believed that practical experience has done more than scientific researches in procuring the high economy of fuel, which has been the result, and that this has been principally effected by the use of high pressure steam expansively employed, and using Mr. Trevithick's boilers, and clothing the steam pipes and cylinders with a non-conducting material, together with great attention of the enginemen to the fires, so as to make the best of every bushel of coals consumed, as some enginemen are now doing on the railways.

"In 1843 the average duty for 94 lbs. of coal was 60,000,000 lbs., while in 1856 it had steadily decreased to 47,000,000 lbs., for the same fuel. It is to be deeply regretted that the duty of our steam engines is decreasing, and that many of the important lessons taught by Capt. Grose appear to be forgotten; whilst we are brought familiar with the rapid improvements of locomotive and marine engines, we have to deplore a retrograde movement of the stationary engines in our Cornish mines. With the present low price of minerals, and reduced dividends, we certainly ought to try to bring up the duty of our steam engines to where it was in 1843. The number of pumping engines reported for January is 37. They have consumed 2,846 tons of coal, and lifted 22·3 million tons of water ten frames high. The average duty of the whole is, therefore, 52,800,000 lbs. lifted one foot high by the consumption of 112 lbs. of coal."

49. *Rotative and Cornish Pumping Engines.*—In par. 27, p. 133 of last year's volume of this work, we gave an article on this subject. In the discussion which followed upon the reading of Mr. Fraser's paper on "Cornish Pumping engines"—Society of Engineers—and of which an abstract will be found at par. 26,

p. 119 of our last volume, Mr. Olrick had the following remarks on this point:—"In comparing the single-acting Cornish engine with the double-acting engine with crank and flywheel, it was impossible to lay down a rule for when one should be used and when the other. The circumstances in each individual case were to be considered, but still it must be remembered that a double-acting engine would do about three times the work of a single-acting engine—that was for the same size and weight—and as it used steam on both sides of the piston, and worked generally twice as fast as a single-acting engine, hence for the same power was much more economical in the first cost.

"It had been said by Mr. William Pole, and illustrated by Watt at an early period, that there was no theoretical advantage in whatever form of engine was used, whether double or single cylinder, as regarded economical effect of expansion. That might be or not, but taking it for granted that that assertion was correct, it was quite a different thing in practice; that was, when the expansion exceeded three or four times, and he (Mr. Olrick), maintained that where an expansion of nine or ten times was required, it could only be done successfully and effectually in a double cylinder engine.

"By taking, for instance, a double cylinder engine with nine times expansion, the otherwise tremendous blow of the high pressure steam on the large piston was avoided by letting the steam first into the small cylinder. From thence it passed into a cylinder of three times the area of the small one, after having been cut off at one-third part of the stroke, thus reducing the high pressure steam three times before it entered the larger cylinder, and consequently there was the same total steam pressure on both pistons. The advantage of the vacuum acting upon a much larger piston than in a single cylinder engine, made amply up for the back pressure against the small piston.

The results got at by some engineers in the navy of the United States, that there was not only no gain by expansion, but even a positive loss, contrary to the experience of all engineers in this country, could simply be accounted for by their experiments being carried on with steam of only a low pressure, by the steam not being in any way superheated, by the cylinders not being *steam-jacketed,* or otherwise protected.

"As to boilers, it was a well-known fact that without a good boiler the utmost amount of saving could not be effected by the engine only. They knew that the reason why Cornish boilers were so efficient in Wales was because they were made two or three times larger than in other places, but that could not be done in a town like London, nor could the system be carried out on board ship. He then referred to some experiments made by Mr. John Elder, of Glasgow, with the view of finding out the temperature of the different parts of a Cornish boiler, which was 33 ft. long, and 5 ft. 6 in. in diameter, with two internal flues of 19 in. diameter. It was found that the temperature over the fire was 3200 deg., over the bridge 1730 deg., on entering the centre flues 1163 deg., on leaving them 800 deg. Thus the furnace of a 9 square ft. per horse power reduced the heat 1500 deg., the shell of boiler of 18 square ft. per horse power, 600 deg., the flues of 20 square ft. per horse power only 350 deg. It would thus appear that, although there was a large amount of heating surface, the evaporative power was very inferior, as the amount of heat taken out of the gases was very small; the conclusion was, that the gases passed along in straight lines, and only the thin strata in contact were cooled down. Only 6½ lbs. of water was evaporated per pound of coal. This showed that our land boilers were still very defective, and he (Mr. Olrick) would therefore call the attention of the meeting to a boiler constructed by Mr. Field, a member of the Society, which, for instance, for a boiler of 100 horse power, only took one-twenty-fifth of the space of Cornish boilers for the same horse power, and would evaporate nearly 11 lb. of water per lb. of coal."

At the same discussion Mr. W. T. Carrington gave an account of the *Pumping Engine at Brooklyn Water Works*, and pointed out the mistake made in designing and erecting it. Of this description we take the following:—

"In the original design of the engine, it was intended to carry the steam in the boiler at a pressure of from 25 to 30 lb. per square inch above the atmosphere, and to cut it off very short, expanding about eight times; the cylinder was, therefore, made large enough to give the proper average pressure for that measure of expansion; but, upon the first trial, it was soon ascertained that the *engine could not be* worked with a greater initial pressure on the piston than a few pounds per square inch above the atmosphere, and that instead of cutting off the steam at one-eighth the stroke of the piston, or at 15 in. from its commencement, it was necessary to cut it off at six-tenths of the stroke, or at six feet from the commencement. Thus not only was all the imagined benefit from large expansion lost, but there were realized all the serious disadvantages of using a cylinder two and three-quarter times too large for the work it had to perform. By using an initial steam pressure in the cylinder of 25 lb. per square inch above the atmosphere, and cutting it off at six-tenths of the stroke of piston, the work done by the 90 inch diameter cylinder, with a stroke of 10 feet, would have been performed by a cylinder of the same stroke of piston, but with only 55 in. diameter. The saving would not have been in the first cost alone, but equally in the after economy; for as the friction and back pressure would have been greatly reduced in per centum of the total average pressure, and as the absolute friction and condensation of steam by the cylinder, developing equal power, would have been less, the duty would have been materially increased.

"*The great oversight committed* was the failure to discern the impossibility of using steam with much expansion in the case of a pumping engine, pumping by the steam direct; and unprovided, by a large mass of matter on the steam side, to be put in motion at the commencement of the stroke of piston, and brought to rest at the end of it. If we suppose the matter (other than the water) set in motion by the engine to have no weight, and the movement of the watery column to be uniform, then the steam pressure on the piston at every point of the stroke would have to remain constant, in order to exactly balance the water load, whose resistance was constant and unaffected by speed. In fact, on that hypothesis, it would be impossible to either increase or decrease the steam pressure above that equilibrium, for the supply of more steam would only accelerate the speed of piston, without increasing the pressure on it, and a decrease of the pressure on the piston by closing the communication with the boiler, would bring it quickly to rest. Under these conditions it would be impracticable to use the steam at all expansively. But just in proportion as matter was added on the steam side could the initial *pressure* be increased on the steam piston above an equilibrium with the water load; for as movement had to be given to that matter in addition to the water load, and endow it with momentum, the communication between the boiler and cylinder could be closed, and the steam allowed to expand as far below the pressure equilibriating the water load as the momentum of the matter could supplement, until the point was reached where the combined steam pressure and momentum were in equilibrium with the water load. In a pumping engine, therefore, the maximum degree of expansion was limited by the momentum of the matter set in motion; the greater that momentum the more expansively could the steam be used. In a word, steam could be used expansively only by advantage being taken of the inertia of matter at the commencement of the stroke of the piston and of its momentum at the end.

"In the Cornish engines employed for pumping out mines the larger weight of matter required, in conjunction with the piston's, to give the necessary momentum for expansions of even three and four times, was obtained from the great length of pump-rod employed—extending from the surface of the ground to the bottom of the mine. If the depth of the mine did not furnish the weight for the desired expansion, it had to be obtained by adding it for that special purpose. But in the design of the Brooklyn pumping engine that essential provision was ignored, and an expansion of eight times was intended with conditions that absolutely prohibited the employment of any expansion whatever. The consequence was, as might easily have been predicted, that, when put in operation, it presented the anomaly of an engine fitted with a momentarily variable expansion gear from which great economy was anticipated, using its steam necessarily almost without expansion. That defect, after being practically developed, was attempted to be made good by the addition of about eighteen tons of cast-iron in the circumference of two semicircles of 14½ ft. extreme diameter, keyed upon a shaft receiving a vibratory movement from the piston rod between the steam cylinder and lower pump. Those semicircles were so poised that the diameter would approach the horizontal at the half stroke, and the vertical at the end of the stroke, in order to give, beside their momentum, the greatest possible leverage at the beginning and end of the stroke—the first for increasing the initial steam pressure in the cylinder, and the last for compensating the decreased steam pressure by the expansion."

50. *Single and Double Cylinder Engines.*—"A considerable difference of opinion," says a writer in the "Mechanics' Magazine," "still exists among engineers as to the respective merits of single and double cylinder engines, and the evidence adduced on either side is of a somewhat contradictory nature. Without attempting arbitrarily to decide the vexed question, we may venture a few remarks upon it, and then leave it for further discussion among our practical engineering readers. *Prima facie* it does not appear that there can be very much difference between the expansion and condensation of steam in one or in two cylinders, supposing the latter to be on the combined high and low pressure system. It would seem that the gross amount of power obtained from a given quantity of steam expanded in each form of engine is the same in both cases. Certainly the power exerted at the starting point is identical. There is not more blow upon the crank pin on the engine first taking steam in the one case than in the other, if we except a slight decrease of pressure which necessarily ensues in the double cylinder engine by the expansion of steam in its passage from the high to the low pressure cylinder. And this is compensated for by a corresponding decrease of back pressure on the high pressure piston, the difference being the decrease of pressure consequent upon the relative areas of the two pistons. In the single cylinder engine the full pressure of steam acts upon the piston prior to the cut-off, and decreases from that to its minimum at the end of the stroke. A considerably different effect is produced in the case of the combined engine, for at the commencement of the stroke the force of the steam in the high pressure cylinder is balanced by the back pressure, *minus* the passage expansion before alluded to. As soon, however, as the piston moves, the pressure decreases in the low pressure cylinder instead of remaining the same through a given portion of the travel, and the back pressure on the high pressure piston diminishes in the same ratio. The high pressure cylinder would do less work if the same force of steam were applied to it on account of its smaller capacity. Hence arises a gradual diminution in the sum of power obtained from the two *pistons from* the beginning to the end of the stroke. The power

which is sacrificed immediately on the starting of the smaller piston is partially compensated for by a gain towards the end of the stroke, for there is obtained the maximum power of the high pressure cylinder added to the minimum of that of the low pressure cylinder." . . . .

After entering into some calculations respecting the working of high and low pressure engines with steam of equal pressure, the writer concludes thus:—"Hence it would appear that a single cylinder is calculated to do a larger amount of duty with the same consumption of fuel, but that it does not distribute its power so equably as two cylinders. For pumping and many cognate purposes the latter arrangement therefore may be deemed best; but where variations in the speed of machinery to be driven are of little moment, undoubtedly the single cylinder engine is the most advantageous motor. The questions of imperfect vacuum and of loss of pressure in expansion consequent on changes of temperature have not been considered in the foregoing remarks, because the relative merits of the two kinds of engine would not be affected appreciably by them."

51. *Notes on Slide Valves.*—We take the three following articles from the "Scientific American:"*—

(*a.*) *How to Set a Slide Valve.*—"In all the works on steam engines which have been written we do not remember to have seen any account of the manner in which a slide valve is set, and we have had frequent inquiries from young—and must we say it—old engineers, who confessed they did not know much about it. It seems strange that any person should have charge of a steam engine and be unacquainted with this simple duty, yet it is a fact indisputable. Many an hour locomotives have stood on the tract helpless from the slipping of an eccentric, which the driver was unable to replace; and mischievous comrades have oftentimes designedly loosened set screws, (in the early days when screws alone held the wheel in place,) so as to cause confusion and subsequent dismissal, to the incompetent driver who could not reset it.

"There are indeed no lack of rules in engineering works which direct us to set the eccentric, something in this way:—

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* The reader interested in this important department of mechanical engineering will find full directions as to setting valves in the 'Working Drawings of Engineering and Machine Making.' A Fullarton and Co. London and Edinburgh.

"'Place the crank in the position corresponding to the end of the stroke (why not say on the centre?) Draw the transverse centre line answering to the centre line of the crank shaft on the bed plate of the engine, or on the cylinder, if the engine be direct acting, describe a circle of the diameter of the crank pin on the large eye of the crank and mark off on either side of the transverse line a distance equal to the semidiameter of the crank pin; from the point thus found stretch a line to the edge of the circle described on the large eye of the crank and bring round till the pin touches the stretched line. When the crank is thus placed at the end of the stroke the valve must be adjusted so as to have the amount of lead or opening on the steam side which is intended to give at the beginning of the stroke, and the eccentric must then be turned around upon the shaft until the notch in the eccentric rod comes opposite to the pin on the valve lever and falls into gear; mark the situation of the eccentric, and put on the catches in the usual way, etc.'

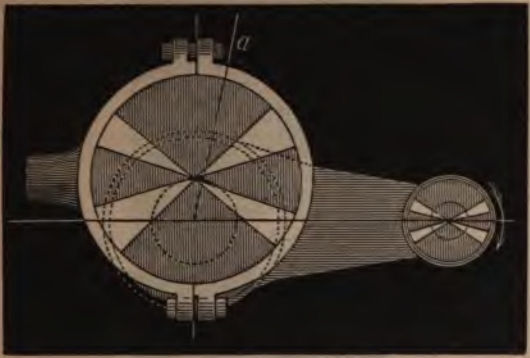
"This long and incomplete instruction is from Bourne's Catechism of the Steam Engine, and we are sorry to say omits one very important thing, so that it would be impossible to set a valve by this method. The omission is in getting the length of the eccentric rod at the outset. Without further criticism or discussion, we shall explain how an eccentric is set.

"Presuming the proportions properly made by the draughtsman at the shop, the first thing is TO FIND THE LENGTH OF THE ROD.

"Put the straps on the eccentric, and connect the valve gear as in working order. Disconnect the engine and slip the eccentric around on the shaft, and observe what takes place in the steam chest. Doubtless the valve will uncover one port clear to the exhaust while the other is entirely or nearly shut. This shows the rod to be too long or too short as the case may be. If the port nearest the crank, in a horizontal engine, is wide open and the other port shut, the rod is too long, and must be shortened half the difference only. We say half the difference, because it must be remembered that what is taken off one end is put on the other, so that the real amount the rod is shortened will be seen in a complete revolution.

"When the valve 'runs square,' as it is called, or opens and *shuts the ports* properly, set the wheel as in this diagram.

Fig. 15.



"The eccentric is always in this position in every instance, whether the engine be vertical, horizontal, or inclined, and the intervention of levers between it and the valve makes no difference in relation to the crank itself. The wide part of the eccentric and the crank are always at right angles to each other, excepting such departure from a right angle as the lead and lap take off.

"The diagram represents an eccentric without lead working a valve without lap. Such a coincidence seldom obtains in practice, and the true position of the eccentric is shown by the dotted line, a; this indicates that the eccentric is turned on the shaft towards the crank, thus pulling open the port behind and driving the crank in the direction of the arrows. If levers are intervened to reverse the motion of the eccentric the crank would go the other way. We are speaking of a direct connection.

"It will be easily understood *why* the eccentric is always in this position, when it is borne in mind that the eccentric must commence to open the valve a little before the crank gets to the centre. In other words, the eccentric must commence its stroke a little a-head of the crank.

AN IMPROPERLY SET VALVE.

"Here is a drawing of an improperly set valve. It is not drawn to scale, but is none the less a correct example. It will be seen that the crank has passed the centre and commenced the

Fig. 16.

return stroke, but there is no lead on the steam side in front at the port nearest to the crank, and before the crank passed centre there must have been much compression in the cylin at the forward end of the stroke. The steam was shut up in cylinder, and its tension or elasticity greatly increased there Steam, like other gases, follows a law discovered in some exp ments by a French philosopher called Mariotte. According this authority, if steam at 60 pounds be shut up in a cylinder *inches long* and the piston in said cylinder be pushed down three inches, the volume will be reduced one half and the pressure will have been raised to double or 120 pounds.

"So when the exhaust closes too soon, say at six inches from the end of the stroke, when the crank is on the centre the pressure will be in proportion to the amount of cushioning or compression. There are many engines working in this condition to-day; should they not be attended to?

"Setting the valve with a link motion is precisely the same operation; the eccentric stands exactly as shown in the diagram. There is only this difference—the lead is somewhat disturbed by the action of the eccentric rod which is not in gear, whether it be the forward or back connection. This derangement causes some change in the lead when cutting off at low grades of expansion; and it is necessary to take this into account when setting the valves. The lead should be given properly on the point the engine is to work at, for since the lesser rates of expansion are only used on emergency, it matters little whether they are correct or not."

(*b*) *The Pressure on a Slide Valve.*—"It is a popular idea that the number of square inches in the back of a slide valve, and the pounds of steam in the chest, represent the total pressure upon the valve. Another delusion is, that the pressure on a slide valve is equal to the pounds of steam per square inch on the back, minus the area of the steam ports. If we consider the valve to be a solid block of iron on a solid table, and mechanically tight, the steam would press on every square inch of surface with the same force that a dead weight laid upon it would. But these conditions are never found in a slide valve, except in one position; that one, when the valve laps over both ports, and the engine is at rest.

"So soon, however, as the valve is moved the steam enters the open port, and the pressure is practically taken off that end of it. When the valve is moved back over the port, the steam that is shut up within the cylinder will press up against the under side of the valve face with a force exactly equal to the pressure at the point in the stroke of the piston at which the valve closed. As the valve continues its stroke the other port will be opened, and the steam we have supposed shut up in the cylinder begins to exhaust; at this time, the pressure against the under side of the valve will be the pressure in the cylinder at the end of the stroke. This pressure is only for a brief period, however, for in a well constructed engine the time of exhausting the contents of the cylinder is very short. While the steam is entering the open port, then, and after the exhaust has passed through the closed port, the pressure on the under side of the valve will be just the ordinary back pressure, supposing the engine to be non-condensing—which is the supposition we have entertained in this discussion.

"It is therefore unquestionable that to determine the pressure on a slide valve we must consider the pressure in the cylinder at the time of cutting off, at the end of the stroke, the area of the ports, the area of the back, and the back pressure on the piston."

(c) *Balanced Slide Valves.*—"A serious objection to the use of slide valves is the great power absorbed in operating them. When this detail of the steam engine is of any considerable size the evil increases to an injurious extent, so that the force required to work the valve is a large per-centage of the whole power of the engine. Indeed, it is not unusual to see slide valves which have an area closely approximate to the total number of square inches on the piston, and if the nature of the work to be done were similar in both cases, the pressure on the piston would be balanced by that on the valve, and the engine would not move.

"The result of this great labour on one part of the engine is followed by the rapid wear of everything connected to or with it. The eccentric straps of screw propellers are often made of wrought iron and bushed heavily with brass, so as to withstand the strain and to avoid heating caused by the excessive friction. The rock shafts are made unusually heavy, the valve stems much stouter, the journals larger and longer, and in fact each detail is very greatly enlarged so that it may be capable of performing the task assigned to it. Thus a larger amount of material is used than is needful, an increase in the cost of construction is apparent, expense in lubricating and repairs ensue, and the whole system is not only defective from an engineering point of view, but vexatious in its commercial aspect.

"Aside from this defect, the slide valve, when properly made, is one of the simplest and most effective ever invented for its *office.* If there were no remedies for the disease spoken of previously, the adoption of the slide valve, beyond certain areas, would be discouraged, but since the ingenuity of man has provided a way of escape, it is singular that so few interested parties avail themselves of it.

"If we were temporarily made a power from which there could be no appeal, we should immediately fulminate an edict against parties using slide valves, and command them, on pain of large annual repairs, and manifest deterioration of their property, to apply some method whereby the pressure of the slide valve would be reduced to a rational amount; no greater than that due to the work required of it.

"When the first invention to relieve the excessive friction of the valves was brought out it was a step in the right direction, but the attempts to introduce this valuable improvement have met with very little encouragement from those most interested. In the cases of large screw propellers which have engines working at high speeds it is absolutely necessary to divide, or take off the pressure on the valve face. Different methods have been adopted to do this. One of the simplest for low pressure engines is that invented by Messrs. Penn, of England. This consists in planing the back and face of the valve parallel, and placing a brass ring between the back and steam chest bonnet, so that the junction is steam tight. This ring covers only a portion of the area of the back, and therefore excludes the steam pressure from that area. A connection is maintained with the space inside of the ring and the condenser, which materially aids in restoring the balance, or reducing the friction of the valve on its face.

"A striking effect of the utility of this contrivance, so far as relieving the pressure is concerned, was witnessed by engineers on the Italian frigate *Re d'Italia.* The condenser communication was shut off when the valves, stems and rods, although of ample dimensions, trembled violently, showing that the resistance to motion was very great. On restoring the connection the valves resumed their previous easy movement.

"Another method is to attach a steam cylinder to the steam chest. In this cylinder there is a piston which the main valve is connected to by links; when the steam is let into the chest it presses equally on the valve and the piston, between the two, so that the pressure is taken off the valve in the ratio of the difference between its superficies and that of the piston. The piston has a slight reciprocating movement to compensate for the stroke of the valve. Vacuum may be maintained on the back of the piston, so that by the combined force of the steam and the absence of back pressure on the piston the valve may be actually pulled off its seat. It is impossible to detail all the ingenious and practical devices for this purpose, but it is manifestly proper that they should be universally adopted."

(*d*) *Improved Balanced Slide Valve.*—"The enormous absorption of power by the slide valve is the greatest objection to its

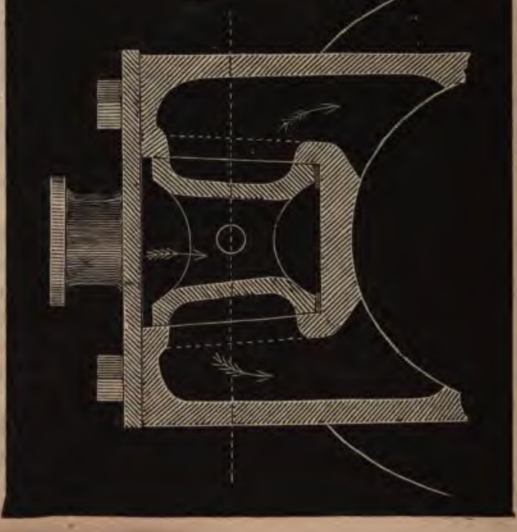


Fig 17.

Fig. 18.

use. Engineers of experience know well how to construct a valve that shall work properly as to the times of opening and closing the ports, and the relation between the steam lead and the exhaust lead, and all are agreed that an efficient, simple and durable arrangement for equalizing the pressure on the valve face is exceedingly desirable. The friction of cast-iron sliding on cast-iron, unlubricated, according to Rennie's experiments, is 1·5 of the weight up to 100 pounds pressure per square inch. From this estimate we can readily see what amount of work is expended in merely moving the valve over the face to let the steam in and out.

"In the engravings published herewith, we have a representation of a new method of balancing a slide valve. No springs, gears, or steam-tight joints or levers are interposed between the valve and cover, but it is of the ordinary form in its general features.

"Two valves are joined together at the back, as in the isolated view, and the ports are made double, so that there are two valves and two valve faces in the chest, instead of one, as heretofore. These ports are constructed as shown in the section.

"The valve faces being inclined, shed any dirt or sediment that may chance to drop upon them or be carried over from the boiler by priming, and from being inclined they wear steam tight, top and bottom, the degree or angle being suited to equalize the wear. The steam passes between the two valves, as shown by the arrow in the section, and, pressing equally against both sides, causes the valves to work freely, and yet steam tight, against the face."

52. *Foundations of Engines.*—In a paper on this important subject, in the "Mechanics' Magazine," under date January 6th, 1865, we find, amongst other remarks, the following:—"Foundations or structures of brickwork for engines are subjected to various strains. In beam engines compression and tension are equal, but rigidity in this case is the most important to maintain. The amount of loading, or brickwork underneath the cylinder, is regulated by the pressure of the steam and area of the cylinder. Should the least disturbance of the foundation take place, the perpendicular line of the cylinder *will be greatly affected,* particularly when the piston is

at the top of the cylinder, or at the full stroke. Securing the cylinder on its bed is also one of the vital operations which regulates the correct working of the engine. The brickwork should in every case be allowed to settle equally, and be loaded for a time to ensure a perfect compression. It is the general rule to introduce bond-timbers to receive the bolt-keys and plates; but, undoubtedly, the better and stronger material for that purpose would be cast-iron, in the form of a frame built within the brickwork. When bond-timbers are laid separately, each side piece is independent of the one opposite it, whereas, with the cast-iron frame, the entire resistance would be equally distributed throughout, and being connected, or in one mass, each point of resistance is counteracted. It may be argued that a wooden frame would accomplish the same object as an iron one. Granted for a time, but rigidity and durability are not so fully developed in the products of the vegetable as in the mineral kingdom. The writer has known instances where the entire loadings of large engines have been built on wooden floorings, in order that the resistances might be distributed equally. This was correct in principle, and in practice has been found to be advantageous. . . . . In building the engine-house, it is often the rule to construct the loading and walls in connection with each other, in order to ensure rigidity. This, however, entails a mass of brickwork, &c., which, by adopting the tubular foundation and loading, would be greatly reduced, and the required strength ensured, by the addition of the concrete, as well as by the peculiar form of the structure. Stones of large sizes are usually used for the bed of the cylinder bottom or plate. In some cases they are connected by wrought-iron clamps, to preserve a solid and even surface.

"The holes for the holding-down bolts are often made large, so that their fitting the bed-plate may be ensured. The use of the key or hand holes below the loading is, as well known, for the purpose of allowing the bolts to be withdrawn when required, in case of breakage; but this accident rarely, if ever, occurs. The gain in the accessibility to disengage the lower end of the bolt when required, is attended with the requisition of extreme tightening, so as to preserve a rigid connection. The *bolt being fixed*, or bearing at each extremity, requires a greater strain on it than when firmly secured the whole of its length. There is no natural law to prevent bolts being secured in the cast-iron or wooden frame below the loading in their respective positions, so that the upper or top ends will fit the holes prepared in the bed-plate, a template of which might be used during the erection of the loading. The structure would then, if the bolts were taper, secure them more rigidly. The doubt may now arise, whether the exact position of the bolts can be maintained during the settling of the structure; the answer to this is,—properly secure the template, so that no disturbance can affect their true positions. The next portion of this subject of vital importance is the securing the bed-plate of the cylinder. When the plate is secured direct on the stone or brickwork, it often happens that, in screwing or tightening the nuts, the original level of the plates is destroyed, and cases have been known where great difficulties have arisen to remedy the deviation alluded to.

"In cast-iron, cohesion is more fully developed than in stone. We find, on securing iron to stonework, the latter, with great compression, scales or crumbles under its superior ally. Also in the case of looseness of contact with constant movement. To obviate these casualties, the better plan would be to employ cast-iron in the place of stone. It may be argued that, as the stronger and harder material still rests on that of the weaker nature, the evils alluded to still exist. This, however, is obviated by the application of the materials employed. The cast-iron top frame should be so shaped that portions of it are embedded in the structure or loading. Area of surface in this case being required to maintain rigidity, the provisions on the frame for the reception of the cylinder bottom should be chipped and filed to their required state after the holding-down nuts and bolts are finally secured; by this means exactitude is ensured, without the fear of deviation. Another gain in the use of the top frame is, that as cylinder bottoms are turned and faced to receive the flange on the cylinder, adjustment by chipping is impracticable to ensure a perfect steam joint. Enough has now been said to evince proofs that scientific principles require as much observation in the construction of foundations of engines *as for their manufacture.*

"Horizontal engines are usually on a smaller scale than those of the beam kind. The usual shape of the foundation of an horizontal engine is a parallelogram in plan. As for beam engines, piling and concrete should be resorted to, to retain a firm surface for building on. The strains imposed by direct acting horizontal engines are not so intense as those of the beam kind. In the latter, if the division of the versed sine of the travel of the beam is not exact, the distance of the centre of motion to the base of the loading acts as a lever to disturb the perpendicular line, but in the horizontal engine the strains are more of a longitudinal than perpendicular nature. Certainly the centrifugal force of the fly-wheel tends to lift the foundation, but this can be counteracted by an increase of weight of loading under the centre of the crank shaft. The main frame, or bed-plate, in most cases, is in one casting; consequently, the area of the surface in contact with the brick or stonework is more than that for the beam engine in relation to the nominal power. Also, in the case of the horizontal engine, the cylinder guides and main bearings for the crank shaft are on one frame; hence no deviation can ensue without distortion, which can only be effected by the uneven tightening of the nuts of the holding-down bolts. To obviate this, care should be taken to turn each nut at the same time. The holding-down bolts should be secured in the lower frame, and built in the brickwork. Those for the crank end are longer, due to the increased depth of the loading, the lower frame being made to suit."

53. *On Piston Packing.*—We find in the "Scientific American" the following remarks:—"When the first pistons to steam engines were made, they were made tight by hemp gaskets,—that is, coils of hemp plaited with rope thoroughly slushed or soaked in hot tallow, and subsequently driven in as tight as a man striking with a sledge could make them. It was a great step in advance when cast-iron rings were substituted for the hemp and steel springs inserted to keep the rings always up to the cylinder. Quite as much ingenuity and thought have been expended on the pistons of steam engines as upon any other detail, and the variety in shape, form, and kind of packing, would make an interesting study for the engineer if they were *all collected* in book form. The pistons of ocean steamers, for

instance, have lighter springs than many small engines, and are not packed so tight, by many degrees pressure, in proportion to their areas, as some engines on land. There are few stationary engines in the country which will pass the centres with two or three pounds pressure on the gauge, but there are plenty of steamboats that have engines which will do this with ease.

"It was formerly the custom to pack locomotive cylinders with brass rings, which had a central lining of Babbitt metal let in. This also is done away with, and the largest works and the heaviest engines on the Erie railroad, and others, for aught we know, have cast-iron rings.

"In many instances pistons have been used without any packing in them—being simply solid disks fitting tightly, yet easily, to the bore. Some concession has been made to prejudices and conventional ideas by turning grooves in the solid piston, and depending on the partial condensation of the steam to fill these grooves with water, and thus interpose an obstacle to the passage of steam between the piston and cylinder. It is probable that the evil of a leaky piston has been much exaggerated, for, although it will show on the indicator diagram when very much out of repair, it is a question whether any great amount of fuel is wasted by such a loss. There is no question, however, but that much damage is done to steam cylinders by bad packing, and many can testify to the scored and seamed cylinders that were made so by forcing in the springs.

"Air pumps have been made for compressing air with solid pistons, and, reasoning from analogy, there seems no objection to making the pistons of steam engines of a moderate diameter of cylinder entirely solid; in fact, many are now working so made, and those who built them, as well as the owners, find no fault with their performance. On the contrary, rings are frequently a source of trouble, and, taken altogether, with their springs, followers and follower bolts, the piston with metallic packing is a costly detail. If lessening the cost of construction, and retaining the vital qualities of any part, is an important feature, then the pistons of small steam engines should be made solid."

54. *Piston Rod Guides.*—We follow up the remarks in last paragraph by extracts from a paper with this title, given under date *September 29, 1865,* in the "Mechanics' Magazine." For

what the writer gives on other points not noted here we refer the reader to the article itself:—"With vertical engines guides are imperative, unless the parallel motion be again introduced, which may be said to be too complicated for pistons moving at high speeds. The many kinds of guides for engines of this class are all the same in principle of action, that is, they retain the perpendicular motion of the rod. Some makers prefer a circular guide, in fact, a prolongation of the piston rod, the same working in an eye or bush. There is great objection to this arrangement, owing to the fact that the strain on the rod at each half stroke of the piston tends to deflect the rod of the same, owing to the fixed locality of the guide. Another mode is to prolong the rod as before, but with a separate portion on one side of the crosshead, the pin for the connecting rod being on the opposite side of the centre line. The guide in this example, as in the last, is fixed, but the piston rod is between the centres of action of the guide and connecting rods. It is obvious that with this arrangement the strains are more evenly distributed than with the circular guide, centrally located and extended so much beyond the centre line of the greatest strain. The evil of fixed guides is so apparent that ere long their adoption will doubtless be discontinued. The true definition of fixed guides is, that the strain on the piston rod is counteracted from a fixed point, and thus disarrangement and deflection are the natural results.

"The mode of adjusting the surfaces is of great importance, as all rubbing surfaces in contact, wear in the direction of the strains enforced. In some cases sliding blocks are used, each end of the crosshead being inserted therein. The blocks work in a channel formed in the framing. By this it will be understood that adjustment was not regarded, and on the blocks and channel becoming worn a jerking strain on the piston rod was the result at each half stroke of the piston. The means adopted to adjust the surfaces in contact are various; in many instances compression or reduction of the space between the surfaces is adopted, while in other cases expanding the guide is resorted to. To define which is the better we must consider the strains and surface chiefly affected. It is universally known that the centre of action of the piston rod must be retained, so that to adjust one side of the guide *only* would be doubtless disturbing the plane line of the rod. In the event of shifting both surfaces, adjusting bolts and nuts must be introduced, thus entailing complication and increase of liability to looseness of detail. The better plan is to adjust the block, and by a single screw, wedge, or key, adjustment can be readily maintained without increase of friction or disarrangement. The guide blocks now in general use have flat, curved, and V-shaped or angular surfaces. The channels in the framing are solid (so to speak), or adjustment is attained by the block only. The first-mentioned surface is the most general, each side or surface being a loose portion and connected by set screws, studs, or wedges. In the case of the curved surfaces, rods are used as guides, and the brasses either clasp the rods or are semicircular in contact; the latter may be deemed the preferable mode, as the outer surface is not in contact unless there be excessive wear on the inner side. The V guide is perhaps the best example, as the shape of guide assists to retain the position of the block, whereas with the flat surface block provisions on the sides are imperative, unless the channels be recessed.

"The next engines for consideration are those adapted for high velocities, or the horizontal type. This detail for horizontal engines is much varied in principle and design. Some makers prefer double guides at the sides of the rods, while others resort to the primitive fixed guide, to which we have alluded. In the case of the double guide it should be remembered that four surfaces are always in contact, whereas with judicious arrangement two faces will be ample, sufficient area being, of course, considered. The action of the connecting rod is to lift and press down the piston rod, such action being, of course, due to that of the crank. When double blocks are adopted another evil exists, unevenness or inequality of adjustment, due of course to the requirements of simultaneous tightening of the guide surfaces. The single block also admits of a better connection with the piston rod, while the guides themselves can be located over and under the perpendicular line of the piston rod, an arrangement which admits of the greatest resistance to the strains imposed. For the better purpose of exemplifying our remarks we will describe in detail the arrangement now under question, which is particularly adapted for high velocities and reverse motions. The guide block is formed either of *gun metal or malleable* cast-iron. The latter, although of late production, is being now extensively used amongst engineers and machinists. Its tenacity is somewhat startling; we have seen specimens tied into knots without fracture—in fact, equal to wrought iron. The space between the wearing surfaces of the block is sufficient to allow for the rise and descent of the connecting rod. The brasses clasp the guide on all sides so that looseness is an impossibility. Adjustment is attained by wedges with stop or set nuts at the front end, which can be further secured by set nuts and studs at the back if required; but this last may be termed an excess of safety, but nevertheless is more secure. The connecting rod, instead of being double at the connection, is single, and inserted in the block instead of clasping it. The pin or crosshead, as in other engines, passes through the block, and is secured at the smaller end by a nut, recessed in the side of the block; the larger end of the pin has a key to prevent its oscillating or shifting in the bearing. The brasses of the connecting rod are adjusted by a cotter and internal rod, the former being beyond the guides if required. The piston rod is secured to the block by a key or cotter, a projection being cast for that purpose. It will thus be understood that simplicity and compactness are maintained, and adjustment is available without disarrangement. The guide channel can either be closed at the sides or open for given spaces. The upper portion of the guide is secured to the lower by three bolts and nuts on each side; lateral disturbance is prevented by recessing the guides reciprocally where connected. This explanation suffices to show the superiority of the arrangement now advocated, economy of construction and repair also being considered. The guides for oscillating engines are the gland, packing, and bush in the stuffing-boxes; the trunnions being also pivots to retain the location of suspension."

55. *Thompson's Portable Engine.*—"Almost every day witnesses the advent of some improvement, or attempt at improvement, in the application of steam power, and especially in the portable form, and the desire for simplicity and a reduction in the number of parts, has led to attempts, almost without number, to construct an engine with a continuous rotary movement instead of a reciprocating one convertible to rotary movement by the action of a crank. It is obvious that a constant stopping and re-

versing must require greater weight and strength than a continuous movement in one single direction. Among the machines exhibited at the meeting of the British Association at Birmingham, was a portable engine by Mr. R. W. Thompson of Edinburgh, on the rotary principle. The boiler is vertical, having a cylinder of 3 ft. in diameter by 6 ft. in height, the internal fire surface consisting of a hemispherical bottom, with the heat spreading all over it by leading to a circle of vertical fire-tubes, passing through the water. To one side of this boiler is attached the engine, which shows externally as a horizontal cylinder, about 12 in. in diameter by 2 ft. in length, within which the pistons revolve, the entrance and exit of the steam being provided for by the action of external elliptical tooth wheels fixed on the revolving shafts, which, causing alternate faster or slower movement of the pistons past each other, opens and closes the passages. A drum-wheel on the axis of the cylinder carries a strap, which will put in motion any required machinery. The whole is supported on one pair of wheels, with a pair of shafts attached, and can be moved by one horse. The machine as shown was stated to be the equivalent of an ordinary eight-horse portable engine, and that the relative weights were 30 cwt., the rotary engine against 55 cwt. on the ordinary plan, while the cost price of the former to the latter was in the same proportion. No flywheel is needed to keep up the movement, and there is an absence of all the vibrating motion induced by the reciprocation of ordinary engines. The principle is equally applicable to portable purposes or to boats or locomotive engines. The actual consumption of fuel for work done was not given to the meeting; but, assuming it to be the same per horse power, there is nothing in the wearing parts of the machine that may not easily be replaced, and at little cost. Every improvement of this kind, placing steam more and more within the reach of every one for all the common labour-saving purposes of life, is a gain to the community. It is probable that this engine, worked by a blazing fire of petroleum, will prove the best and simplest, as well as the cleanliest, moving power applicable to ship's launches, which is now found to be almost a necessity of modern steamships, economising the strength of seamen by getting rid of the labour of the oar. Getting rid of weight in this machine is a very important matter, by allowing a larger amount of fuel, as well as facilitating the hoisting in and out."

56. *Double-Cylinder Revolving Steam Engine.*—The "Scientific American" describes an engine of this kind, the invention of J. L. Foster of Virginia:—"Rotatory engines, in one form or another," says the writer, "have occupied the attention of inventors for many years, and changes in the form or details of them, with a view to render them economical and efficient, are continually being made.

"This engine is not a rotary engine, inasmuch as the pistons in such machines travel continuously in one direction, but this combines a reciprocating motion of the piston with a rotary one of the cylinder, and adds the weight and momentum of that detail to the force exerted by the piston.

"The following description will render the principle and main parts familiar to the reader:—The cylinders are fixed on the face of a wheel at the opposite ends of its diameter, this wheel being set below the centre of the shaft and pulley, half the length of the stroke. When, therefore, steam is admitted to the pistons, they, on being forced out, act against the crank which is placed between the cylinders, and turn the cylinders and wheel round.

"The steam is let into the cylinders by ports, through the the steam pipe and exhaust pipe. There are two branches to both of these pipes, and when steam is let into one, by turning a valve the engine revolves in one direction, and is reversed by admitting steam to the other branch. It is intended to have two sets of cylinders, or four in all, the piston rods crossing each other at right angles, and one pair of cylinders set further from the shaft in order to allow the rods to work on different cranks on the same shaft. The yoke is fitted to a bearing in the central shaft, thus distributing the labour on the main shaft. By having four cylinders there is no dead centre, and the force is continuous at all times. Packing rings keep the wheel steam-tight at the point where the steam is introduced. These rings fit in a circular chamber behind the wheel, and are made in sections so that the entire chamber will be prevented from losing steam by the expansion of them in every direction. The *cylinders* are lubricated by a cup on the steam pipe. This engine, says the inventor, is particularly useful for propellers, on account of the ease with which it may be reversed, and the velocity of piston it is capable of attaining. It is also claimed to be simple and efficient, and that two revolutions of the pulley are obtained from one reciprocating movement of the pistons."

57. (*a.*) *Defects of Steam Engines*—(*b.*) *Horse Power*—(*c.*) *Expansion of Steam.*—On these three topics we take the following suggestive paragraphs from the "Scientific American:"—

(*a.*) *Defect in Steam Engines.*—"Zealous professors of science occasionally call attention to the fact that steam, as a motor, costs much more than it should, and that little over one-tenth of the actual heating value of the fuel is realized in practice. Experiments and experience prove the statements to be virtually correct, and it is a reproach to the mechanical skill of the period that it should be.

"The loss is not in the theory of the engine, for that is perfect, but in the practice of that theory; or, in plain terms, in the construction of steam engines. It is an undeniable fact, however, that but few of the steam engines now constructed work with the economy that they should, or even approximate in performance to the theoretical value of the fuel.

"Portable engines are turned out by scores which, although well enough externally, are far from being in a healthy condition in those parts which affect economy. The slide valves are only such in name; they exercise few of the proper functions of this most important detail, and the boilers are heavy, enormously large in fire and heating surface, and every way disproportioned to the size of the cylinders. The feed pumps are poorly got up; the valves lift too much; the water passages are cramped and crooked, and the absence of any proper method for heating the feed water without creating more loss from back pressure on the piston than is gained by injecting hot water to the boiler is oftey noticeable. We make these statements for the interest of ann it may concern, not to find fault. Many stationary engines are in precisely the same condition.

"It is not the only thing required in a slide valve that it shall open and close the ports at a certain time, but that it shall be *properly set for the work it* has to do, that it shall exhaust the contents of the cylinder at the proper time, that it shall close properly, and that the lead shall be proportioned to the duty. That this is important every one is aware who has ever inspected, or is familiar with, indicator diagrams.

"It is a common thing on railways to hear a locomotive exhausting "one-sided," as it is termed, or giving palpable public evidence that it is out of order, and that the master-mechanic on the line is either indifferent or careless of his duties. We know of one road where our ears are daily saluted by the sound of a locomotive drawing a long train of coaches, and regularly exhausting 1-2-3—4, 1-2-3—4, or with a very positive interval between the successive exhausts. It would be quite as sensible to draw two or three empty coaches day after day, as it is to permit an engine to run in this way; for at every uneven or irregular interval the steam is compressed or choked in the cylinder, and delayed in getting out until it acquires a high tension, so that the actual pressure is much greater on the exhaust side than on the steam side. This subtracts from the efficiency of the machine, adds to the cost of repair, of fuel, and every thing used in running the engine. A locomotive engine exhausting unequally carries dead weight, which costs a great deal to keep.

"We know that engines are often regarded as in chronic or incurable difficulties, because some mysterious cause conflicts with setting the valves properly, but we have frequently found that individuals were more fond of declaring that the defect was very mysterious, than they were zealous to remedy it.

"It is very plain from the simple facts here cited—many of which are so well known among professional engineers as to be truisms—that one of the greatest obstacles in the way of economy in the steam engine, is a want of mechanical accuracy in construction, erection, and oversight, and that the cost of a horse-power could be very much reduced by attention to obvious and well-known defects existing in steam engines."

(*b*.) *Horse Power.*—"When Watt began to introduce his steam engines he wished to be able to state their power as compared with that of horses, which were then generally employed for driving mills. He accordingly made a series of experiments, which led him to the conclusion that the average power of a horse was sufficient to raise about 33,000 lbs. one foot in vertical height per minute, and this has been adopted in England and this country as the general measure of power.

"A waterfall has one horse power for every 33,000 lbs. of water flowing in the stream per minute, for each foot of fall. To compute the power of a stream, therefore, multiply the area of its cross section in feet by the velocity in feet per minute, and we have the number of cubic feet flowing along the stream per minute. Multiply this by $62\frac{1}{2}$, the number of pounds in a cubic foot of water, and this by the vertical fall in feet, and we have the foot pounds per minute of the fall; dividing by 33,000 gives us the horse power.

"For example:—A stream flows through a flume 10 feet wide, and the depth of the water is 4 feet; the area of the cross section will be 40 feet. The velocity is 150 feet per minute—$40 \times 150 = 6{,}000 =$ the cubic feet of water flowing per minute. $6{,}000 \times 62\frac{1}{2} = 375{,}000 =$ the pounds of water flowing per minute. The fall is 10 feet; $10 \times 375{,}000 =$ the foot-pounds of the water fall. Divide 3,750,000 by 33,000, and we have $113\frac{21}{33}$ as the horse power of the fall.

"The power of a steam engine is calculated by multiplying together the area of the piston in inches, the mean pressure in pounds per square inch, the length of the stroke in feet, and the number of strokes per minute; and dividing by 33,000.

"Water wheels yield from 50 to 91 per cent. of the water. The actual power of a steam engine is less than the indicated power owing to a loss from friction; the amount of this loss varies with the arrangement of the engine and the perfection of the workmanship."

(*c.*) *The Expansion Controversy.*—"If a cubic foot of air be suffered to expand to a volume of two cubic feet, and its temperature be kept constant, its pressure will be reduced one-half. The same law applies to all permanent gases, and this is the famous Mariotte law—half the volume, double the pressure. An essential condition is that the temperature be kept constant. Tyndall contends that when air expands, without doing any work, as when it expands into a vacuum, its temperature is not reduced by the expansion; *but all* physicists are agreed that if the air *in expanding performs* work—overcomes resistance—it is cooled, and, consequently, its pressure is reduced to less than that assigned by the law.

"It was formerly taught in the books that steam expanded in accordance with the Mariotte law, but it was discovered many years ago that so large a portion of the steam is condensed into water as to cause a very wide departure from this law. What the amount of this condensation is—to what extent it balances the work theoretically due to expansion, and, consequently, whether there is economy in working steam through large measures of expansion—is a problem which has proved to be one of the most difficult of solution of any that has occupied the attention of philosophers.

"On the 18th of November last, Professor W. J. Macquorn Rankine, of Glasgow University, in a communication to this paper, stated the law of the expansion of steam under five different conditions, concluding with the case of a steam engine, in these words :—

"'When the steam expands and performs work in a conducting cylinder, which receives no supply of heat from without, but is left to undergo a great alternate rise and fall of temperature through its alternate connection with the boiler and the condenser, the law of expansion becomes very variable, and the problem of determining it extremely complex. It is certain, however, that a great waste of heat occurs in every case of this kind, as Mr. Isherwood's experiments have shown. In a paper read to the Institution of Engineers in Scotland, about two years ago, I discussed some of Mr. Isherwood's earlier experiments, and showed that they gave proof of a waste of heat, increasing with the fall of temperature, due to the expansion of the steam, with the extent of conducting surface of the cylinder, and with the duration of the contact between the hot boiler steam and that conducting surface.'

"The great compeer of Rankine, in this department of physics, is Regnault, of France. In a paper published in the London and Edinburgh *Philosophical Magazine*, October, 1854, he thus states the difficulties of the problem :—

"'For my own part, I have long laboured to bring together the experimental data by means of which the theoretical motive power produced by a given elastic fluid, which undergoes a certain change of volume, as well as the quantity of heat which becomes latent by this change, might be calculated *à priori*. Unfortunately these data are very numerous, and most of them can only be determined by extremely delicate and difficult experiments."

58. *Engine Power, Nominal and Actual.*—From an able paper under this title, by Mr. John Imray, in the "Scientific Review," for December 1865, we take the following extracts:—"Among companies or private persons ordering steam machinery, it is tacitly understood, if it be not distinctly specified, that the indicated power shall very largely exceed the nominal; and an engineer working strictly in accordance with the letter of his contract, would be thought either unsuccessful or dishonest if his engine did not do something like three or four times the work nominally required of it. He might even, as matters now stand, be subject to heavy damages in a suit at law; because it could be proved, by overwhelming evidence, that the custom is to furnish *actual* power very much exceeding *nominal*—in other words, to reckon eighty or ninety ounces to the pound, or 10,000 or 12,000 lbs. to the ton.

"It may be interesting to inquire how this custom originated, how far it acts prejudicially to the interests of both producer and purchaser, and how it may be best abolished.

"If we were to define *power*, we should say that it signified the capability of doing certain *work* in a certain *time*. And, still farther defining the terms we use, we should say that *work* means the movement of a certain *pressure* or *resistance* over a certain *space*. The kind of pressure or resistance with which we are best acquainted, which is most uniform and most conveniently measured, is the gravitating attraction exerted by the earth on masses of matter near its surface. We thus come to take *weight* as the standard of pressure or resistance, and select some unit of weight—such as 1 lb. avoirdupois, or 1 kilogramme in the French metric system—as the unit of pressure or resistance. In the same manner, we select 1 ft. or 1 metre as the unit of linear space over which the weight is moved when work is done, and 1 minute as the unit of time in which it is effected. We readily see that to move 10 or 20 lbs. over 1 ft. involves 10 or 20 times the *work required to move 1* lb. over 1 ft.; also, that to move 1 lb. over 10 or 20 ft. involves 10 or 20 times the work required to move 1 lb. over 1 ft.; and thus we determine that *work* is proportional to the *weight* moved, and also to the *space* over which it is moved, and consequently, that it is proportional to the product of the *space* by the *weight*, and must be expressed by a number which means neither *feet* nor *pounds* simply, but feet multiplied by the number expressing pounds, and called, for the sake of abbreviation, foot-pounds. Thus the work involved in moving 3 tons over 12 ft. is estimated as 3 × 2,240 × 12 = 80,640 ft.-lbs.

"It is evident that *work* alone, without taking *time* into account, gives no measure whatever of *power*. A mouse, carrying grain by grain, may remove a ton of wheat over a considerable distance. A horse, taking it altogether over the same distance, does no more work, but he does it in less time. And the power of the horse is to that of the mouse in the inverse proportion of the time occupied by each in doing the same work. Taking, then, the element of *time* into account, we have simply to divide the product which represents the work in *foot-pounds* by the *time* in minutes occupied in performing it, in order to obtain a result which represents in *foot-pounds per minute* the *power* of the animal or engine employed.

"In most cases, the numbers resulting from this arithmetical computation are large, and would be difficult to remember, and troublesome to operate with. It would be as if we kept our cash accounts in farthings. In order to reduce them to convenient figures, we adopt a tolerably high standard of power—a constant number of foot-pounds per minute—*viz.*, 33,000, by which we divide our product: just as we should divide our number of farthings by 960 to reduce the amount to pounds sterling. This standard we call a horse-power, by which we mean literally the power of one horse, or its capability of doing work. It was adopted by Watt, not without care and reflection, founded, as it was, on the average of many experiments actually made with horses, and probably no good reason can be assigned for altering it. Practically, however, it is now altered, for, instead of 33,000, it is put variously at 100,000, 150,000 or 200,000, according to the avidity of the purchaser of a steam-engine, or the emulation of *its maker.*"

After pointing out how "step by step, 1-horse *nominal* power had come to be 6-horse *actual* or *indicated* power," the author concludes thus—"It is inconvenient, in any case, to have no fixed standard of weight, measure, power, or anything else that is to guide transactions of purchase or sale. It is still more inconvenient in matters of science or art, where accurate measurement of results is of the highest importance as a foundation for future operations. But over and above the inconvenience, there is an immorality, a dishonest greed on the one hand, which asks more than it has a right to expect, and an unfair competition on the other, which gives more than is asked, merely to throw others into the background. It is time that this should cease. If the old-fashioned standard of horse-power is defective, let a better be substituted; but let it at least be a fixed and constant quantity, to which all the world can appeal, without reference to what some do or do not, or to any custom or usage whatever. Let us suppose a case (and it is no ideal one) of a farmer who orders from one engineer a threshing-machine, and from another a steam-engine to drive it. The one states that, to drive his machine effectively, 6-horse power is required, the other undertakes to furnish that power. The machine and the engine are erected and connected, but they will not work. The maker of the machine explains that the engine has not power enough; the maker of the engine states that the machine would take a great deal more than 6-horse power. The engine is tested by the indicator, and is found to give out 9-horse power; it is also tested by the dynamometer, and, owing to the necessary friction of its moving parts, gives somewhat less, say 7 or 8-horse power. The very same strap that worked on the dynamometer is applied to the threshing-machine, and all the conditions are unchanged, but still the combination does not work. The maker of the machine immediately appeals to the custom of making engines to give out a power double or treble their nominal, and asserts that if that custom had been adhered to the machinery would have gone sweetly along. The maker of the engine, on the other hand, hints that threshing and other machines generally take more than their stated power, and reprehends the custom of so understating the force required.

"*Surely a state of things* which permits such anomalies to occur should come to an end. It is not as if there were no means of testing accurately power emitted from an engine or absorbed by a machine. The indicator, on the one hand, with reasonable allowance for friction, and the dynamometer on the other, with no allowance at all, settle those questions beyond appeal, and no point is left for dispute except that allowance in the case of the indicator, which might be settled once for all by a few carefully-conducted experiments, and which, at most, can amount only to a moderate per-centage of the whole power. The results of my own observations on small non-condensing engines (from 5 to 20-horse power), tested both by indicator and by dynamometer, give a loss by friction and other resistances of 15 to 20 per cent. of the indicated power. As a convenient average, I should take about 17½ per cent.; and, fortunately, this allowance renders the computation of power very simple, as may be understood by the following example:—

Assume that an engine gives an indicated power of 100 horses, which means that it is equivalent to 3,300,000 ft.-lbs. per minute: for the number 3,300,000 divided by 33,000 (the standard horse power) gives 100 horses. Now, taking 17½ per. cent., or 17½ horses from this for friction, &c., the remainder, 82½ horses, is the quotient, after dividing 3,300,000 by 40,000. Hence, to compute the effective or dynamometric power, the rule is simply to divide the foot-pounds per minute indicated by the constant number 40,000, or to point off 4 places and divide by 4. I do not, of course, insist on the perfect accuracy of this standard; on the contrary, I think it is a point which should be determined by engineers of experience. Whether right or wrong, it would be certainly better to adopt it than to go on without any standard whatever. At all events, let some standard be adopted, and let it be sanctioned by the practice of engineers of repute, and, above all, by Government Boards: who should be the first to regulate for the public—by example, at least, if not by direct law—matters which admit of accurate adjustment, and the adjustprat of which would tend so much to the public advantage."

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put vari **SECTION SECOND.—LOCOMOTIVE STEAM ENGINES.**

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its maker;omotive Reform.—We open this Division of our work very appropriately with an abstract of a paper under the above title in the "Mechanics' Magazine," under date, February 3d, 1865. After pointing out that since the "Rocket" was placed some thirty-five years ago on the Manchester and Liverpool Railway, very little, if any, change has been made in *the principle* of the locomotive, the writer proceeds by showing the "two special items" connected with the present system, which involve the Railway Companies in heavy outlay. These are (1) the carrying, or unremunerative wheels in the locomotive, and (2) the heavy six-wheeled tenders. The numerous attempts to overcome these evils show their importance; so great indeed is the loss arising from them, that the writer insists upon this that there exists a *necessity* for a radical change in the present system of locomotive construction. "The tank engine," he says, "is good in its way, but is at best only adapted for short runs with light loads, where a sufficiency of water and fuel can be carried without overloading the wheels, and for velocities not exceeding 25 to 30 miles an hour. But under the present system no one would venture to construct a tank engine to draw heavy loads from Rugby or Peterborough to London. To do so would require a tank, and coal bunkers, of the necessary capacity to carry water and fuel sufficient for such a trip without stopping, and thus the wheels would be so overloaded that they would not be able to run at all. Were it possible to do this the injury resulting to the permanent way and wheel tires would be enormous. The difficulty of overloading the wheels by the tank and bunkers might be got rid of by distributing the weight over a larger number of wheels, but then the distance between the leading and trailing wheels would be too great, causing enormous side friction, and increased danger in running round curves. To obviate this the bogie principle has been introduced, but with very questionable result. When the bogie is adopted in eight-wheeled engines it is found to be of very little use, inasmuch as the framing of the driving and trailing wheels is distinct from that of the bogie, and the boiler being stayed to the framing, is perfectly rigid for the whole of its length. The bogie-pin is fixed on the smoke-box end of the boiler, and so the bogie wheels can only run in the plane of the direction given to them by the *framing and* boiler. But these bogies do swivel occasionally, while their not doing so generally shows that it must take a very sharp curve, necessitating a great deal of force to move them. If the two pairs of trailing wheels could be arranged to swivel like the leading ones, the case would be very different, for then the trailing wheels would accommodate themselves to the curve on which they might happen to be travelling without influencing, as at present, the plane or direction of the leading wheels. But it is simply impossible to place a bogie frame beneath the fire-box end of the boiler as at present arranged, and, if possible, the difficulty would be to transmit the power of the engine through the wheels with moveable centres, to the rails.

"The weight of material required to construct a tank and fuel bunkers on an engine capable of carrying the same amount of water and fuel as a tender, would be one ton for every ten tons required for the tender itself, nearly the whole weight of the tender being comprised in the wheels, axles, springs, and framing. If such a tank and bunkers were placed on an engine it would bring about 11½ tons additional weight on the wheels. This would comprise 25 cwt. of material, 7½ tons of water, and 3 of fuel. This extra weight could not with safety be placed on the six wheels, four tons being the safest and most economical working weight that should be placed on each wheel. This may be increased to 5 or even 5½ tons on each wheel, but to go beyond this is to inflict serious injury on the permanent way. In passenger engines on some lines, however, as much as 16 tons has been put upon the driving wheels in order to get bite, and the average may be taken at 14 tons; but this has been found so destructive, both to the way and the tires, that, where possible, passenger engines are built with four driving wheels instead of two, which gives more tractive force and less wear on the wheels and rails. It is true that, by coupling two pairs of wheels, there is a loss of power, but this is more than compensated for by the extra weight gained on the rails; so of two evils the less has been chosen, weight on the rails being important for heavy traffic. This is considered so much so in France and Austria, that as many as eight or ten wheels are coupled, with a weight of from 40 to 50 tons on the rails, but this arrangement is advantageous only on lines having curves of large *radii.*" In another part of the paper, the writer makes a remarkably useful suggestion, and on a point so important, that it appears strange it has never been before thought of, namely, the system of "having the principal parts of locomotives interchangeable," or duplicated. It is abundantly evident that if this was done, the repairs of engines would be speedily made, and all delays we know are costly. The writer then concludes, "Enough has already been said to prove that much could be done, in saving the every day expenses of railway companies, and it appears strange that locomotive engineers have never attempted some change towards the removal of the objectionable tender, or the introduction of duplicate parts. But the truth is, that irrespective of responsibility to be incurred, the demands upon the time of a locomotive engineer are such as to leave him but little margin for the consideration of any revolutionary measures if he were so inclined, and so he is content, if not compelled, to continue in the old tract.

"But after all that has been said on the subject, it is satisfactory to be enabled to point out a way of escape from the trammels of a system which can raise such insuperable objections to any and every point of improvement advanced. If this, that, or the other, being pressing necessities, cannot be done under one system, it is wise to consider how far another system ensuring their accomplishment should be adopted. If, under the old well-digested principle, the locomotive is helpless to fulfil the conditions the advancements of the age demand of it, then it is clearly time to initiate the adoption of any proposition bearing on its face evidence of mature consideration in design, and a fitness for its intended purpose. An arrangement calculated to overcome all the obstacles herein enumerated would prove a great boon, not to railways alone, but to the public in general, who are becoming more and more identified with them and their interests. With the view of meeting these contingencies, and of overcoming the manifest evils of the present locomotive system, Mr. Fairlie, the engineer-in-chief of the Central Railway of Venezuela, has proposed a novel arrangement of locomotive, an illustration of which will be found on another page. Therein he proposes to effect the required improvements, and in the following manner:—Firstly, by the construction of the boiler, which is so arranged that, according to

Mr. Fairlie, a greater generating and maintaining power can be obtained than by any possibility can be by the existing system. Secondly, by the whole weight of the engine, including fuel and water, being made available on the rails for traction power. Thirdly, by tenders being entirely dispensed with as useless, unremunerative, and costly. Fourthly, by the general arrangement of the engine complete, by which it is enabled to pass round any curves down to a radius of one and a half chains with the greatest facility, and the friction due thereto is reduced to a minimum. Fifthly, by doing away with the necessity for turntables at termini and at locomotive depôts; and Sixthly, by reducing the expenses of the epairing shops to a minimum, together with the expenses arising from a want of a system of duplicates, as, by the plan he proposes, the most complete system of duplicates can be carried out.

"If this new principle be found practically to embody all the inventor claims for it—and reason is not at variance with favourable expectations—it will indeed successfully surmount the obstacles which at present so impede railway traction, and will in itself constitute a great stride in the perfecting of the locomotive engine. The question has been taken up by several eminent engineers, and locomotives upon Mr. Fairlie's principle are in course of construction. One railway company at least has adopted the system. It may therefore not be long before opportunity is afforded for judging how far practice will coincide with theory in respect of this invention."

60. *Tank Locomotives.*—This subject was taken up and partly considered in the article in preceding par. In an article in the "Engineer," under date April 14th, 1865, considerable space was devoted to a somewhat lengthy discussion of its bearings. Of this we give the following extracts, referring the reader to the article itself for the remaining portions. After pointing out the losses incurred by the "tender" system on account of the repairs it involves, the writer proceeds:—"Nor is the question of repairs confined to the tender proper, the machine indirectly, but very effectually, operates for evil by materially promoting the destruction of permanent way, especially about stations. Engines get over a good many miles yearly merely in shunting, an operation during which a tender is to all intents and purposes a useless *incum*brance. We have said that it constitutes the heaviest

carriage met with in a train, if we except royal saloons, and its powers of mischief are proportionately great. There can, of course, be no good reason advanced for hauling about a load of fifteen or sixteen tons every time that an engine or a couple of empty carriages require to be moved over a few hundred yards of rail. But, unfortunately, it is easier to point out the evils of the separate tender system than the means of abatement. Locomotive superintendents regard the matter very much in the light suggested by their individual temperament. One man accepts the tender as a necessity which the engineer of the line looks upon as the result of a cruel fate, while another tries to make capital out of the grievance, and either 'goes in' for extraordinarily long runs, or fits cylinders beneath the foot-plate and utilises the otherwise objectionable weight for adhesion. There is such a thing, however, as trying for too much, and now and then a driver, however careful, makes a mistake on these long runs, and finds himself ten miles from the nearest water crane with half an inch of water over the roof of his fire-box, and a tender tank full of moist air. Probably the longest run at present adventured upon without refilling the tender is that from Euston-square to Rugby, and in slippery weather it is often found expedient to stop at Wolverton for water, rather than run the chance of emptying the tender when yet far from home. Mr. Sturrock's system—the revivification of an old idea worked out in France years ago—is hardly more promising. The auxiliary tender may serve a sufficiently good purpose in the case of goods engines, but it would be utterly out of place in an express train; and in any case we are disposed to believe that the judicious use of sand will be found a less costly and quite as effectual a method of obtaining the amount of adhesion required to work up all the power which an ordinary boiler is capable of developing.

"It may be, and often is, advanced, that it is hardly fair to select the tender of an express engine as representing the habitual weight of such machines. This we will grant as being true to a certain extent, but even when the quantity of water carried equals but 400 or 500 gallons, and of fuel but 7 cwt. or 8 cwt., the separate tender still operates for evil, and not for good. These small tenders are notoriously heavier in proportion to the load they carry than those of full size, and as the only legitimate excuse that can be brought forward for using such a device at all lies in the fact that water and fuel enough can be carried for very long runs, such an argument simply cuts the ground from beneath the feet of the advocates of the system instead of strengthening their cause. Besides, heavy tenders are by no means confined to express locomotives. Goods engines, although they travel at a slower speed, and make shorter runs than their brethren, nevertheless are so heavily loaded that they, perforce, evaporate much water in accomplishing short distances. The very heaviest of tenders may be found forming a component portion of goods stock. In point of fact, the evil pervades almost every section of the railway system, and it is far better to look it straight in the face than to endeavour to underrate its importance, or to gloss it over by sophistical argument. If it can be proved that it is absolutely necessary to carry 1,000 or 1,200 gallons of water in the regular course of business there is an end of the matter; but so long as this question remains a question, its discussion is advisable.

"It is sufficiently obvious that there is nothing to be hoped for in the way of reducing the quantity of water required for the performance of a given duty. It is certain that very little steam is wasted in the modern locomotive, and that although it is just possible that improvements may yet be introduced by which a still higher duty may be realised from each pound of water evaporated than that now usual, the gain must still be so comparatively trifling that it cannot conduce to the suppression of the tender. In point of fact, then, the question is exceedingly simple. Some water must be carried, inasmuch as it is impossible that the suction-pipe of the feed-pump or injector can dip continuously beneath the surface of the water contained in a trough laid at the side of the line. It only remains to be determined exactly how little or how much water must be carried; and this, again, resolves itself into a question which can only be solved by determining the distance which can be suffered to intervene between the watering stations. On an average stations are less than ten miles apart, and as 250 gallons, or thereabouts, will more than suffice for a much longer run, it follows that, provided the working conditions of the traffic permitted the train to stop at each station, no difficulty whatever would be experienced in dispensing with the tender, and carrying the limited quantity of water required on the engine. Such a condition, however, can only be imperfectly fulfilled. In the case of parliamentary trains stopping at every station, tank engines would answer every purpose, and on some lines the principle has been carried out with advantage. But nominally it is not easy to set aside a number of engines for one class of work, and no other. Much greater distances are traversed without a stop than the water carried in a tank of practicable dimensions forming part of the engine would suffice for; and, therefore, either the tender must be used, or recourse must be had to some system by which water can be picked up while the train is running. In this principle apparently, the solution of the problem must be sought, and Mr. Ramsbottom's labours have already been attended with so much success that we are disposed to believe that by the extended adoption of the water trough, tank engines may be rendered capable of performing the longest runs ever required with all the ease and certainty desirable."

After pointing out the desirability of carrying out Mr. Ramsbottom's plan, and considering the difficulties attendant upon its adoption in certain distances and how they can be overcome, the writer proceeds to the character of the engines :—"Esthetically speaking," he says, "a tank engine is seldom handsome. The machine requires skilful artistic treatment to compensate for the absence of the tender. As far as mere beauty of outline is concerned, however, the taste of the engineers will be offended by an outside cylinder engine, with a rather long foot-plate, and the tank disposed beneath it and the barrel of the boiler. There is a practical objection, however, to this arrangement, in the fact that the water has to rise to the feed pumps or the injector. The feed pumps of locomotives commonly give but little trouble, catching hold readily when required, simply because the water in the tender flows directly into their barrels by its own gravity. Every leak in the suction (?) pipe is a water, not an air leak; and even when the engine is at rest, by opening the pet cock, water can be caused to flow directly through the pump, expelling the air. Under such conditions the pumps would feed water at 212 deg.; and they frequently do it, too. A lift of even a couple of feet, however, from a tank below, instead of above the foot-plate, alters the state of affairs materially, and thus the feed apparatus of such engines often gives a great deal of trouble. It is undoubtedly better, in a mechanical point of view, to arrange the tanks on either side of the engine above the frames, and, under proper treatment, a very good result, artistically speaking, may be so produced. While such a system is available, it is not easy to see on what grounds the use of the saddle tank can be excused. It is of all others the ugliest arrangement which can be adopted, at the same time that it is in several ways the most inconvenient and unmechanical. Whatever system may be decided upon, it is almost needless to say that it must be one to which the scoop is applicable; a condition, by the way, which fortunately precludes the use of the saddle tank. In skilful hands, we see little reason to doubt that in the development of Mr. Ramsbottom's system will yet be found a means of superseding the tender, by engines carrying somewhere about a ton more than would otherwise be necessary, in the shape of tanks and coal bunkers. The advantages likely to ensue are too apparent to require further comment at our hands just now."

This paper was followed by one, under date May 12, 1865, with an acticle, of which we give an abstract in next paragraph. This article gave rise to a very lively and unusually protracted discussion in the pages of the "Engineer," to which we refer the reader interested in the subject.

61. *On Condensing Locomotive Engines.* (By Zerah Colburn, Memb. Inst. C.E.)—After pointing out that, although locomotives are worked at nearly three times the boiler pressure used thirty years ago, still the average cylinder pressure is not now much greater than it was then; say, on an average, 40 lbs. upon the square inch of piston. This arises from a variety of causes; and of this, the loss from total back pressure amounts to more than one-fourth of all the steam generated. "That is, from 15 to 18 lbs. of the total pressure upon the pistons is absolutely lost, in addition to whatever steam may be in the cylinder, in excess of the back pressure, at the moment when the exhaust port begins to open. It is, virtually, this excess of pressure above the back pressure, which gives force to the steam blast. Thus, steam of 40 lbs. above the atmosphere escapes into the air with a velocity of more than 1,650 ft. per second, and steam of even *10 lbs. pressure* has an effluent velocity of more than 1,200 ft.

per second. After the steam has fallen to the minimum back pressure, the motion of the pistons still forces out what is left with considerable velocity. Thus, with two 16 in. pistons, moving with an average velocity of 900 ft. per minute, the waste steam pumped out by them, after the evacuation by exhausting, would pass through a 4 in. blast-pipe with a velocity of 480 ft. per second; and this rush of waste steam must assist in keeping up the draught, although its effect is altogether inferior to that of the steam exhausted by its own elasticity. If the steam thus pumped up the chimney were condensed, at the moment when the exhaust steam had fallen to the ordinary limit of back pressure, thus leaving the draught to be maintained by the voluntary exhaust alone, a direct removal of say 12 lb. per square inch from the load upon the pistons would result; a diminution which, with 16 in. cylinders, 22 in. stroke, and 6 ft. wheels, would correspond to an additional tractive force of 939 lb., sufficient for the draught of nearly 40 tons over a good level line at a speed of 40 miles per hour. Or, if this increase of power was not desired, the steam might be worked more expansively, or at a lower pressure, or in smaller cylinders; and, in any case, a saving in the total quantity of steam required would be effected, a saving equal to the amount of steam usefully condensed. The plan of throwing the exhaust steam into the air until it has fallen to the pressure of the atmosphere, and then condensing the remainder, has been often proposed, but not in connection with locomotive engines, where the advantage from such a practice would be greatest. Such a system of partial condensation is described in an old patent, No. 5,857, and in a later one, No. 12,783, and it is figured in Dr. Alban's work on the high-pressure engine. The object, in at least one of these cases, appears to have been the saving of condensing water, which would be of great importance on a locomotive engine, while the exhaust of the steam, down to atmospheric pressure, in the ordinary manner up the chimney, would still provide for the draught. If the draught were found to be weakened from the loss of the back pressure steam, now pumped up the chimney, it is probable that the loss would be more than compensated by employing an annular blast-pipe, say 8 in. in external, and 7 in. in internal, diameter of the orifice; thus nearly quadrupling the surface of action of the steam upon the waste gases in the smoke-box, as compared with a 4 in. blast-pipe. When live steam is employed as a 'blower' in the chimney, its effect is known to be greatly increased, in proportion to the quantity used, by discharging it in a number of small jets, the real advantage of which is their comparatively extended surface of action; and the same effect should result by discharging the same quantity of steam in a thin sheet or ring, having the same total surface. By making the blast-pipe orifice annular, the inductive or exhausting effect of the steam would be increased by the extension of the surface of action; while, with the same total area of opening, the back pressure would not be increased. The tube forming the inner circle of the blast orifice should be open at the bottom, so that a portion of the hot gases could be drawn directly through it, and carried up the chimney surrounded with waste steam. This tube should be easily removable, so as to permit of clearing out the hard carbonaceous scale which often forms in blast-pipes. Fragments of this scale, handed to me by Mr. Maw of the Great Eastern Railway, are 1¼ in. thick. Whether it be wholly a concretion from the tallow supplied to the cylinders (for it is freely combustible), or whether it is partly formed of soot precipitated in the blast-pipe when the engine is standing with a newly-made fire, it is not easy to determine.

"If the steam were condensed in a locomotive engine down to a pressure of 1 lb. above a vacuum, or to a temperature of, say 100 degrees, something of the advantage thus derived would be lost by the cooling of the cylinder, or at least its inner surface, to that temperature. But, at considerable piston speeds, this condensation, so far as it can be estimated from that in the cylinders of fixed engines working under like circumstances, would not be great, nor would it greatly deduct from the advantage by condensation.

"With 16 in. cylinders, 2 ft. stroke, and 6½ ft. wheels, the quantity of steam of, say slightly more than atmospheric pressure to be condensed, would be about 1,560 cubic feet per mile, the corresponding volume of water being, say one cubic foot. To condense this amount of steam to a temperature of 100 degrees would require 22½ cubic feet, or 146 gallons of condensing water at 50 degrees. Taking the consumption of water for evaporation as 20 gallons per mile, that required for condensation would exceed it nearly 7½ times. The feed water would, of course, be taken from the hot condensing water."

The writer then proceeds to show a modification of Ramsbottom's plan of picking up water, which might be adopted for the supply of the condensing water, and proceeds thus:—"At a speed above 11 miles an hour, the advancing motion of the train would raise water from the trough to a height of 4 ft., and this would be sufficient for the purposes of the condenser, air-pump, and injector. The water would be raised into a small tank of, say 200 gallons capacity, under the boiler or footplate. Thence it would be taken directly into the condenser, and from the hot well the requisite quantity of feed-water would be forced, either by a pump or by the injector, directly into the boiler. The tank would, as a rule, be kept full and running to waste, although this would be capable of easy regulation, the waste water flowing back again into the trough. With nearly a ton of water always at command, any incidental loss in stopping, or in running over portions of the line where the trough was up, would be compensated for.

"The coal would be carried in small bunkers upon or near the footplate, and thus the tender, as a separate carriage, would be dispensed with wholly. The weight of a small tank of condensing water, of a supply of coal, a condenser, air-pump, and hot well, would not, altogether, much exceed the diminution of weight which would result from the additional disposable power obtained by condensation. In other words, with an engine in which one-fourth or more of the whole power now pumped up the chimney was saved, a smaller and lighter boiler would be required to generate the steam for a given power, and the saving in weight thus effected would nearly or quite compensate for the extra weight of the condensing apparatus, and even for the condensing water and coal carried. The weight of the tender, therefore, would be wholly saved, say from 8 to 12 tons empty, besides an average load of from 3 to 6 tons of coal and water, the 'average load' being always one-half the weight of coal and water on starting full on a journey. . . . .

"*Care would, of course,* be required to keep the water trough clean, and to prevent its freezing in winter. In a high northern climate, with deep snows and severe frosts, it could not be adopted in the manner described. The engines could be equally worked without condensation, and the line would equally permit of working the engines with tenders, whatever provisions might be made for dispensing with the latter. The engines would have a pump, whereby they might raise water from the trough when standing.

"It should have been observed at an earlier stage in the present article, that a single slide valve, with the passage employed in Haswell's valve, and covering separate exhaust ports to the blast-pipe and condenser, will effect the required disposal of the waste steam, sending part of it up the chimney, and the rest into the condenser.

"It will be remembered that, but a very few years ago, it would have been thought impracticable to supply locomotive tenders with water from fixed troughs while the train was in rapid motion. The idea had been often broached, and it had been made the subject of an early American patent. It was reserved for Mr. Ramsbottom to mature the plan to an extent admitting of its adoption in working the traffic of the greatest line of railway in the world. There was much—very much—to be worked out in the light of experience, and, unquestionably, in the present proposition, as, indeed, with almost everything new, there would be much to be fixed from the results of practical trial. But if water can be kept always clean and liquid in troughs a quarter of a mile long, why can it not in troughs over an entire line? And if a scoop will take it up properly from one short trough, why will it not take up a very much smaller quantity from each one of a continuous series of short troughs? So far as the mechanical details are concerned, they are all practicable, and are, indeed, already matured, almost as far as they well can be without trial on the large scale. When really, if ever, brought into use, the whole system must be worked out by locomotive superintendents themselves, who should be able to do as much without the instigation of patentees. Whether the details already suggested should or should not be found preferable, it is as demonstrable as anything in the mathematics of railways can be, that to save the whole cost, *weight, haulage*, and repairs of the tender would be to save a very considerable cost of working. A tender must be made not only to take, on starting, twice its average load over a given distance—a condition but seldom imposed upon any other class of rolling stock—but it has also to serve as a distance piece between the engine and train, and to withstand, therefore, all the shocks from sudden starts and stops. Hence its great necessary strength and weight, and the cost of working it.

"It is true that the system now proposed, so far at least as the continuous water-supply is concerned, does not necessarily involve with it the system of condensation. But if a continuous supply of water can be had, there is nothing to prevent, and everything in favour of, the condenser and air-pump. In a goods engine, with 18 in. cylinders, 2 ft. stroke, and 5 ft. wheels, a vacuum of 12 lb. corresponds to 1,555 lb. of additional tractive force, equal to the draught of 100 tons at ordinary speeds on a level. It might be urged that a goods engine would often run at too slow a rate to raise water into a tank by inertia (for it is inertia alone which causes Mr. Ramsbottom's scoop to act). The speed would have to be very slow at which the scoop would not act, however—less than 12 miles per hour for low lifts. In standing over a trough the engine could always draw from it, and in working a speed of more than 12 miles per hour should be accumulated before a tank of 200 gallons was emptied. An engine that was nearly helpless with its load, being barely able to crawl, would, no doubt, be compelled to stop often for water, but such an engine would have no right upon a main line of railway.

"The resistance opposed by a sharp scoop receiving a column of water of even 3 square inches of section would be almost insignificant, even at high speeds.

"Instead of a feed pump the tank of 200 gallons might be made as a drum, or, at any rate, well stayed, and a vacuum quickly formed in it, when it would, upon making the proper connections, almost instantly fill itself from a trough beneath it.

"The whole system, based, as it would be, upon the success obtained by Mr. Ramsbottom, will, no doubt, yet receive the attention of railway engineers, who, by perfecting and adopting it, will assuredly contribute in no small degree to the more economical working of railways."

62. *On the Distribution of Weight on the Axles of Locomotives.*

—From a paper read by Mr. John Robinson of Manchester, before the Mechanical Engineers' Society, we take the following extracts:—"Amongst the causes affecting the steadiness of locomotive engines in motion, and thereby also the general steadiness of trains on railways, the distribution of weight upon the various axles, it is believed, has not received the amount of consideration the subject deserves. There are numerous circumstances which must necessarily be taken into consideration for determining the position of the axles of an engine relatively to its general mass. The most important object is to obtain sufficient weight upon the driving wheels, whether single or coupled, for giving the amount of adhesion necessary to draw the load and ascend the gradients for which the engine is to be adapted; and another consideration of great importance in fixing the position of the axles is the number and sharpness of the curves on the road along which the engine has to pass. These two conditions naturally influence the distance between the several axles of the engine, especially the extreme ones, the distance between which is called the 'wheel base.'

"These two main conditions, of the weight on the driving wheels and the nature of the curves on the line, being fixed, the question arises how best to distribute the weight of the engine on its axles. Locomotives in general may be divided for the present purpose into fifteen classes, each of which presents different obstacles to obtaining a proper distribution of weight upon the axles. The figures indicating the weights at the several axles are taken with an ordinary working quantity of water and fuel in the boiler and fire-box, and in the tank engines, with the tanks fully loaded."

After describing the four-wheeled engines usually employed for mineral traffic, the writer proceeds to the class of engine employed for passenger traffic. This has "six wheels all uncoupled, the middle or driving axle being placed under the cylindrical part of the boiler, in front of the fire-box, the leading axle behind the cylinders, and the hind axle behind the fire-box. In arranging an engine of this description, it is usually sought to have the greatest weight upon the middle axle, then a less weight upon the leading, and a still less weight upon the hind axle; but to have these weights not so disproportionate as that it shall be impossible to vary the weight upon the middle axle, within a moderate range, by a corresponding adjustment of that upon the leading axle. In this respect the inside-cylinder arrangement presents an advantage over that with outside cylinders; since the leading axles in inside-cylinder engines can be placed much nearer to the smoke-box, and the weight upon it thereby diminished, on account of the cylinders not interfering with the leading wheels, as in outside-cylinder engines. The connecting-rod also is then capable of being made longer, in consequence of the increased distance from the smoke-box at which the middle axle may be placed without throwing too much weight upon the leading axle, which, in engines with short boilers, is often a matter of considerable importance. It may be remarked, that the arrangement of uncoupled engines with all the axles under the cylindrical part of the boiler is now almost discarded, at least in this country; since they are found to be so unsteady, in consequence of the overhanging weight of the fire-box, that high speeds cannot be safely accomplished with them.

"In an example of inside-cylinder passenger engine, having cylinders 15 in. diameter by 20 in. stroke, middle wheels 5 ft. 6 in. diameter, and leading and hind wheels 3 ft. 6 in. diameter, the total weight, being 26·06 tons, was distributed as follows:—leading axle, 8·16 tons; middle axle, 10·10 tons; hind axle, 4·80 tons; total adhesion weight, 10·10, the weight required for adhesion being 14·48 tons.

"The construction of uncoupled engines with tanks is not of very frequent occurrence. As, however, many such engines were made formerly, the distribution of one is given, with the tank placed under the footplate behind the fire-box: inside cylinders, 15 in. diameter by 20 in. stroke, middle wheels 5 ft. 6 in. diameter, leading and hind wheels 3 ft. 6 in. diameter. The distribution was:—leading axle, 7·35 tons; middle axle, 10·25 tons; hind axle, 6·95 tons; total adhesion weight, 10·25 tons—the weight required for adhesion being 14·48 tons. The placing of a tank under the cylindrical portion of the boiler in an outside cylinder uncoupled engine simply tends to increase the weight upon the leading axle, already too heavily loaded, and has not been extensively adopted within the range of the writer's observation.

"During the past few years there has existed in this country a growing tendency to adopt engines with four coupled wheels for the passenger trains on the great trunk lines, and for the mixed trains on shorter and branch railways. In the former case, in consequence of the great number of passenger carriages required in many of the trains; and in the latter, owing to the desirability of having engines of sufficient power to work trains composed partly of passengers and partly of goods. In most cases such engines have been built with small leading wheels, and with the middle and hind wheels coupled, under the impression that it is safer to run at high speeds with wheels of small diameter in front than if their size was such as is usually employed when coupled for driving. In regard to the best distribution of weight upon the axles of such engines, it is evident that the difficulty is, whether, in the case of inside or outside cylinder engines, to get a fair proportion of weight upon the hind wheels, so as to justify their being coupled to the middle wheels, assuming the position of the hind axle to be behind the fire-box. And to show that this question is not easy of solution, the following instances are given of the distribution of weight upon the axles of such engines.

"Coupled passenger engine with outside cylinders, 16 in. diameter by 22 in. stroke, middle and hind wheels coupled 5 ft. 7 in. diameter, leading wheels 3 ft. 7 in. diameter—total weight 31·60 tons: of which the distribution is:—leading axle, 10·80 tons; middle axle, 11·85 tons; hind axle, 8·95 tons; total adhesion weight, 20·80 tons—the weight required for adhesion being 17·83 tons. In this engine a heavy cast-iron block was added, forming the foot-plate in order to obtain the above distribution of the weight.

"When it is desired, as is not unfrequently the case, to construct such engines for carrying their own supply of fuel and water, it is easy so to arrange the position of the tanks as to get an excellent distribution of weight upon the wheels; and if the tanks be conveniently placed on the side frames, pretty equally over the coupled axles, the loading and unloading of the coupled wheels, in moderately equal proportions, is secured, when the tanks are first filled, and afterwards gradually emptied, by the *supply to the boilers*; whereas, when the tank is placed under the foot-plate, the hind axle has a much larger proportion of the gross weight of the engine to carry when the tank is full than when it is empty. The weights obtained in an engine of this class, with cylinders 15 in. diameter by 20 in. stroke, middle and hind wheels 5 ft. 0 in. diameter, leading wheels, 3 ft. 6 in. diameter, have been:—leading axle, 8·50 tons; middle axle, 10·13 tons; hind axle, 9·51 tons; total adhesion weight, 19·64 tons—the weight required for adhesion being 15·94 tons.

"One of the most generally useful classes of engine for the common purposes of railways is the six-wheeled engine, having the four front wheels coupled, since it can be used for ordinary goods trains, or for heavy passenger trains when not run at too great a speed. The advantage of such an arrangement of engine, if made with inside cylinders, is that nearly the whole weight of the engine may be conveniently distributed upon the four coupled wheels, leaving but a small proportion for the hind wheels, which, in this case, do little more than serve to avoid the disadvantages of an overhanging fire-box. The following is a good example of distribution of weight on the axles of an engine of this class, with inside cylinders 16 in. diameter by 22 in. stroke, leading and middle wheels 5 ft. 0 in. diameter, hind wheels 3 ft. 6 in. diameter:—leading axle, 9·77 tons; middle axle, 10·27 tons; hind axle, 4·42 tons; total adhesion weight, 20·04 tons—the weight required for adhesion being 19·91 tons. . . . . .

"Engines of this class are sometimes required to carry their own supply of water and fuel; in which case it seems most desirable to place the water tank on the top of the boiler, so as to increase the load proportionately on the coupled wheels, and let the hind wheels carry the increased weight involved in the fuel boxes and fuel. The distribution of weight in a 'saddle' tank engine, having inside cylinders 14 in. diameter, by 20 in. stroke, leading and middle wheels 4 ft. 9 in. diameter, is:—leading axle, 9·60 tons; middle axle, 11·24 tons; hind axle, 5·07 tons; total adhesion weight, 20·84 tons—the weight required for adhesion being 14·59 tons. Should it be desired to add tanks to engines of this class with outside cylinders, it is clear that a certain amount of the superfluous weight upon the leading wheels might be counterbalanced by placing the tank under the foot-plate; but the disadvantage would still continue of disproportionately loaded axles, according as there was a greater or less quantity of water in the tank.

"The next class of engines to be referred to is that used for heavy goods traffic with all six wheels coupled. Such engines, constructed with inside cylinders, are very common, though a good distribution of weight upon their axles is not easy, since the hind axle, when placed behind the fire-box, has naturally but a comparatively very small proportion of the weight of the engine to carry; and if, in order to obviate this disadvantage, it is sought to move the middle axle nearer to the cylinders, the due length of the connecting rod is sacrificed unless the length of the boiler be increased, giving a corresponding increase in the wheel base of the engine; which, in railways having sharp curves, is by no means desirable, especially in an engine having all the wheels coupled. A favourable distribution of weight in an engine of this kind with inside cylinders, 16 in. diameter by 24 in. stroke, and wheels 5 ft. 1½ in. diameter, is:—leading axle, 10·60 tons; middle axle, 10·90 tons; hind axle, 7·25 tons: total adhesion of weight, 28·75 tons—the weight required for adhesion being 21·18 tons, and the wheel base 16 ft. 3 in.

"As a mean between the extremes of the last two examples, stands the six-wheeled goods engine, with long fire-box, having the grate sloping upwards from front to back. In this case the wheel base is shortened, and the weight on the hind axle, which is placed under the ashpan, is increased, as compared with engines having the hind coupled axle behind the fire-box. The distribution of weight in such an engine, with inside cylinders 17 in. diameter by 24 in. stroke, and wheels 5 ft. diameter, has been:—leading axle, 10·64 tons; middle axle, 11·57 tons; hind axle, 9·73 tons: total adhesion weight, 31·94 tons—the weight required for adhesion being 24·53 tons, and the wheel base 15 ft. 6 inches.

"With regard to the general principles of distribution of weight upon the axles of six-wheeled locomotive engines, it seems to be the common opinion that the middle axle, to which the power is first applied from the cylinders, should carry the greatest weight, and next to this the leading axle, thus leaving the lightest load to be borne by the hind axle; this arrangement being thought desirable, with a view to keep the front of the engine heavier on on the rails than the hind end, and so secure it from risk of jumping off. The writer would, however, suggest whether such a necessity for placing a greater load on the leading than on the hind axle really exists; since it seems unlikely that any engine, with a reasonable weight upon the leading axle, and consequently with a reasonably strong spring for keeping the wheels down on the road in the event of blows being received, could ever leave the line merely because the hind axle carried a greater amount of weight than the leading axle. It should further be remembered, that in all cases where the hind wheels of an engine are coupled, and the leading wheels not so, an arrangement which is becoming more and more frequent, it is absolutely desirable, in order to obtain the maximum adhesion, that the hind coupled wheels should carry a weight nearly equal to that upon the middle wheels, and consequently greater than that usually placed upon the leading wheels. In this respect there is a disadvantage in the employment of engines with outside cylinders, because of the greater weight of the front part of the engine in that arrangement, and the consequent loss of a larger proportion of the total weight for adhesion. This objection applies only to outside cylinder engines having their leading wheels uncoupled; but, on the other hand, to couple the leading wheels of such engines involves considerable complications and difficulties.

"Another point of interest connected with the distribution of the weight is the effect produced upon the stability of a locomotive by the difference between the portion of weight carried upon each spring and the total weight carried by the rail at each wheel; in all the preceding examples of distribution that have been given, the weights stated are those upon the rails at each axle. In engines with inside cylinders this difference is often very considerable, and must exercise a great influence on the tendency to rise and fall on the springs; and often when, in taking account of the weight upon the rails only, the front pair of wheels is found to press upon the rails with a less weight than the hind wheels—the fact is lost sight of that the weight upon the leading springs is greater than upon the hind pair, and the tendency to leave the road is consequently diminished in front. This arises from the circumstance that, in the case of the middle and hind coupled wheels, the weight of the parts not carried by the springs—namely, the wheels, axles, axle-boxes, springs, and gearing—is greatly in excess as compared with the weight of the corresponding parts not carried by the front springs."

SECTION THIRD.—MARINE ENGINES.

63. *On Marine Engines, from* 1851 *to the Present Time.*—The principal feature of the year, so far as regards papers read before our scientific societies on the subject of the present Division is concerned, was that under the above title, by Mr. N. P. Burgh, before the Society of Arts. From the great length of this exhaustive paper, it is impossible to find space for it within the necessarily narrow limits of our volume. We can, therefore, only refer the reader to periodicals, as, for instance, the "Civil Engineer and Architects' Journal," where it was reported *in extenso*, and give here and there an extract of some of its most interesting departments. Mr. N. P. Burgh, after comparing the marine engines exhibited at the Great Exhibition of 1851 with those in 1862, proceeds, for those readers who are not professional engineers, or who may not be connected practically with this department, to specify the necessary component parts of a pair of marine engines of the present day. These, he says, "consist of cylinders, pistons, slide valves, piston rods, slide casings, expansion valves, blow-through valves, piston rod guides, connecting rods, cross heads, main frames, crank shaft, eccentrics, rods, links, valve rods, guides, condensers, air-pumps and valves, injection valves, shifting valves, discharge valves, bilge and feed pumps, valves for the same, starting gear and turning gear, lubricators, and all the necessary levers, bolts, nuts, &c. It will thus be seen that marine engineers have more difficulties to contend with than is generally known. To understand the use and real character of each of the above details is not the work of weeks or months, but years. It should not be forgotten either, that the honour of our nation, and the lives of its representatives, are often in the hands of the marine engineer. I will now proceed with the descriptive illustration of details, showing defects, improvements, and suggestions for the future, commencing with slide valves.

These valves govern the entrée and exhaust of the steam to and from the cylinders. Two kinds or classes of valves are now universally used, the common and the equilibrium; the former is so well known that a description of it is scarcely necessary. I will only observe that its use for larger engines is much on the decrease, on account of the stroke of the valve being due to its outside lap, which for large ports is considerable. Equilibrium valves are so called from the equal action of the steam tending to lift the valve from, as well as to press it on its facing. These valves are double-ported to reduce the stroke. One firm has lately introduced three-ported valves, to still further reduce the stroke. In order to reduce the friction of the valves on the facings, rings are used encircling the body of the valve, adjustment being gained by screws, ratchets, and springs to prevent looseness. In some cases, a communication from the back of the valve to the condenser is arranged, to still further reduce the pressure on the valve facing. Slide rods are usually one to each valve, but, latterly, two have been introduced for large valves, which, no doubt, greatly assist in guiding the valve during its action.

"The next portion in rotation will be that for working, reversing, and stopping the action of the slide valve, universally known as the 'valve-link motion.' . . . The object of the link motion is to reverse the action of the slide valve without disconnection. The links now in use are of two kinds, slotted and solid. The slotted link has the sliding block within it, whereas that of the solid kind slides within the block. The means adopted for raising and lowering the link are various. One maker prefers to use a lever, secured on a weigh-shaft, passing over the front part of the cylinders, motion being given by a worm and wheel, the former being keyed on, or forming part of the starting wheel shaft. Another firm deems it better to impart motion to the lever by a ratchet and pinions. A third authority raises and lowers the link by a rod connected to a block surrounding a coarsely-pitched screw, motion being given to the screw by mitre gearing; whilst another firm prefers to fix the block, with the screw to be elevated and lowered. These two last are undoubtedly the most powerful of the examples given.

"The systems at present adopted for guiding the slide valve rod are of three kinds. First, the dove-tailed guide, similar to that used by tool-makers for the arm of a shaping machine. Secondly, a block of gun metal sliding on two fixed turned rods as guides over and under the valve rod. Thirdly, the valve rod secured to a square bar, working in a bracket, and cap to correspond. This last may be said to be the most simple, but perhaps not so rigid as the first example. The double guides are complicated, but at the same time produce the rigid resistance to the strains imposed on the valve rod by the vibration of the link.

Some makers of marine engines prefer to allow the link to rest or hang on the block pin, inserted in the lever of the slide rod weigh-shaft. Such a practice dispenses with guides. Excessive vibration of the link on or in its block greatly deteriorates the action of the valve, it being understood that, whilst the link has an ascending or descending motion, as well as sliding, the strain on the valve rod is increased, and, at the same time, the stroke is affected. The excess of the vibratory motion is painfully perceptible in the ordinary slotted link; the eccentric rods being connected beyond the block pin, a direct action cannot ensue. The distance between the centres of the eccentric rods and block regulates the amount of indirect action. Links of this kind are often hung from a rod connected in the centre to the link, either to the clip or at the back. This is far better than at the lower end, as the connection of the suspension rod regulates the ascending and descending motion of the link whilst at work. The link resting on the block, when for going ahead, obviates to a certain extent some of the evils alluded to. The gain by the introduction of the solid link, with the eccentric rods connected at its extremities, is strength with less material, but the vibrating motion is not decreased. In order to obtain a more direct, and, if possible, a perfect action, the eccentric rods have been secured to the link, so that the centre of connection may be on that of the block, and by this the vibratory motion is effectually got rid of. . . . .

"It now becomes necessary to treat of the suspension or lifting rods for solid links; for this a few words will suffice. As the ascent and descent of the link whilst in motion are governed by the length and position of the rod, it is almost needless to state that the suspension rod should be connected in the centre of the connection of the eccentric rod. The link, when for going ahead, should be down. It may now be argued that the vibration of the link, when for going astern, must be excessive. Granted, but as the forward motion of the ship is of the most importance, it is not unfavourable to economy to adopt the connection alluded to. In some cases the solid link is guided at the top or bottom, but this is only required when an overhanging or outside connection of the eccentric rods is resorted to.

"The next portion for consideration is the expansion valve and gear. The use of this valve is to allow the steam to be cut off at the early or given part of the stroke of the piston, and the expansion or elasticity of the steam completes the power required. Now it is certain the use of high-pressure steam for large cylinders and short strokes produces excessive shocks at the commencement of the strokes, and thereby entails an increase of strength in the materials used, so that the proportions are larger than for ordinary purposes. It is clear also that, when steam is admitted at an excessive pressure against the piston suddenly, it (the piston) receives an impetus equivalent to the power imposed; and in no case whatever could an engine of proportions for low-pressure resist the strains imposed by the use of high-pressure steam. The ordinary pressure adopted by marine engineers is from 20 to 30 lb. per square inch, more often the former than the latter. I am not aware, however, of any cause why 60 to 80 lb. should not be adopted, with a great increase of economy and power. Of course the present proportions of engines and boilers would have to be increased if the same materials were used, but steel boilers, shafts, and rods, might be introduced with considerable advantage, embracing great strength with less weight.

"Having alluded to the ordinary pressures at present used, it will be well now to advert to the expansion valves. These valves are of three kinds, throttle, slide, and tubular.

"The motions imparted to the throttle valve are oscillating and revolving, the latter is now most generally adopted, but with this disadvantage, that the action is equal both for supplying and cutting off.

"The slide valves are of the ordinary and gridiron type, the latter may be said to be the better, on account of the stroke *being so short in comparison* to that of the former.

"Tubular valves are tubes inserted in each other, with ports to correspond, a sliding or rotary motion accomplishing the desired effect. The motions imparted to these several valves are generally uniform, either by mitre gearing or eccentrics, consequently the action of the valves is not perfect. . . .

"The piston rods of marine engines are subject to excessive strain, consequently the use of guides is imperative. For the single piston-rod engine, the universal system is a channel underneath the rod, the guide-block being generally of gun-metal, and the upper portion attached to the piston-rod by bolts and nuts. For double piston-rod engines the guides are of two kinds, the first arrangement is as the last, and the second, as for high pressure engines or double guides. To say which is the preferable mode of arrangement of guides will, perhaps, be deemed bold, but I may venture to state that I deem that for the single piston-rod the best of any yet introduced.

"I cannot close this portion of the present paper without alluding to the admirable arrangement for tightening the gland of the piston-rod stuffing-boxes, introduced by the firm of Messrs. Maudslay, Sons, and Field. The screws are of the ordinary kind, but, in the place of nuts, worm-wheels are used, worms being fitted to correspond; and motion can be given by a box-spanner while the engines are at work. This is one of the most important improvements tending to accelerate the progress of a ship during a voyage of, say three or four months. Imagine the engines requiring stoppage during a gale in order to tighten the glands, and a fair estimation can be formed of the value of the improvement alluded to.

"Having commented, though somewhat briefly, on the cylinder appendages, attention may now be given to the main frames and crank-shaft. The main frames may be said to undergo a continuous strain, and must, consequently, be of a certain strength in order to preserve the requisite rigidity. The cylinder is attached to the one end, and the condenser at the other, whilst the crank-shank has to be supported in its bearings. Not many years ago a celebrated firm used to make the condenser and main frame in one casting; since that we have had the well-known frame, like the letter A laid on its side, also the hollow frame, with a raised projection for the crank-shaft, and a stay from the upper portion connected to the cylinder; this last may be said to be the most simple, and, at the same time, of less material than the A frame. As before stated, the strains on the frames are continuous, yet, when sudden shocks occur, from the racing of the engines or the priming of the boilers, the tenacity of the cast-iron is severely tested. As this is the case, wrought-iron might be used with great advantage, both as to increase of strength and decrease of weight. The crank-shafts of marine-engines are generally of wrought-iron, in one mass, the cranks being double, and forged with the shafts. Three bearings are deemed imperative, so as to equally distribute the strains. . . .

"The arrangement of the ordinary condenser and air-pump for oscillating paddle-engines is generally as follows: the condenser is situated between and below the trunnions of the two cylinders; the air-pumps are at an angle, with trunks and connecting rods of the ordinary kind; the foot valves are at the bottom of the barrel of the pump, the piston has valves in it; and the discharge-valve, when not at the top of the pump-barrel, is at its side. Now, the principal defects in this arrangement are in the position of the valves and condenser. When the foot-valves are directly underneath the pump's piston, it is obvious that an almost entire disconnection must be made to inspect them. Also, in the case of the piston-valves requiring inspection, the pump-cover must be removed, and to attain this the gland packing has to be slackened, and the connecting rod disengaged. Now, to avoid these evils, doors might be introduced, but with these disadvantages—increased height or length of the air-pump passages, and a body of water always above and below the piston, which undoubtedly is what any right-thinking engineer would disapprove of, it being clearly understood that an air-pump will produce a better vacuum when the piston thoroughly discharges the contents between the foot and delivery valves at each stroke. . . .

"The next portion of the subject now before us is the ordinary condenser for screw engines. The action of the air-pump in this case is usually horizontal, consequently the valves are at right-angles to the pump. To describe each arrangement of condenser and air-pump that have come under the writer's notice would *occupy too much time,* consequently a brief mention of two or three examples on this occasion will be deemed sufficient. For direct-acting and trunk engines, with the cylinders secured together or side by side, the condensers were between, and in some instances in front or at the sides of the air-pump. The foot and discharge valves were directly over each other, the former under the pump at each end, the condensed water or steam being drawn through the foot valves and forced through those above. In another instance the foot and delivery valves were extended the entire length of the air-pump and passages, the position of the valves over and under being as before, and the condenser being between the air-pumps. For return connecting-rod engines, the condenser and air-pumps are subject to great disadvantages. In order to obtain a passably good arrangement, and at the same time occupy a moderate space in proportion to those last mentioned, the condenser, &c. have to be shaped to suit the purpose required. It must be perfectly understood that when the piston-rods are beyond the crank-shaft, as in the examples now in question, there is a certain amount of space required for the piston-rods and guides of the cross head or guide block, whichever may be used. It is also clear that accessibility to all the valves without disarrangement should be attained. To illustrate these desiderata, the following examples will be sufficient for the present purpose. In one instance the condenser is partially between the cylinders, and extending beyond the crank-shaft; the air-pumps are at the side of the condenser; the suction-valves extend the length of the air-pump, and the discharge-valves are between each pump, the pump and the valves being beyond the crank-shaft. . . . .

"The portions of the marine engine next for exemplification are the feed and bilge pumps. The position of these is so arranged that a free access can be obtained to the valves and surrounding parts without disarrangement. Some makers prefer to work the feed and bilge pumps in a line with each other, with one rod and plunger direct from the steam-piston. Other firms secure the pumps side by side to the discharge water-pipe of the condenser, each plunger being connected to the piston-rods crosshead; this latter improvement is more general than the former. In the case of hollow plunger or trunk air-pumps, those for the feed and bilge are on each side of the air-pump, and secured by nuts or keys. Before terminating this portion of the subject, it will be well to add that the valves for the air, feed, and bilge pumps are now universally discs of india-rubber, instead of the gun-metal spindle-valves. . . .

"I have come to the end of my brief description of the marine engine, and will now allude to the weight of material, cost of marine engines, and the relation of nominal to actual horse-power, together with the consumption of fuel. The variation in the weight of marine engines is due to the design and arrangement as much as the material used. Double trunks may be said to be a fair example as to the average weight of marine screw engines. Return connecting-rod engines are perhaps the heavier, in comparison to those of the single type, in relation to rods and guides. High and low pressure engines combined are the heaviest of any examples yet given. The materials comprising the different portions of the engines of the present day are of six kinds—first, cast-iron, of which is formed the cylinders, pistons, valves, casings, main frames, guides, condensers, &c.; secondly, wrought-iron, comprising cranks and shafts, piston and valve rods, links, levers, weigh-shafts, bolts, nuts, &c.; thirdly, steel for springs, small pins, &c.; fourthly gun metal for bearings, guide blocks, bushes, glands, nuts, &c.; fifthly, copper, for pipes of all kinds required for steam and water; sixthly, india-rubber, for valves, packing, &c. For the present occasion, in reference to weight, I have selected twelve examples of marine screw engines, each varying in power and design. The examples of arrangement being in pairs, the result has been that 4·334 cwt. per nominal horse-power may be taken as the average weight of material, exclusive of boilers, fittings, screw-propeller, and alley-shafting. It may here be observed that each maker of marine engines in the present day differs in design and arrangement, consequently, the weight of trunk engines by different makers would be unequal. The same may be said for single piston-rod engines, as well as for double piston-rod return connecting rod engines.

"I now come to that portion of this subject which is the crowning question of all, and too often the cause of much controversy in political and commercial circles—viz., what is the cost? My opinion is, that it is perhaps the most difficult query to answer *that could be put*, and the only reason for its introduction is to preserve myself from presumed neglect in not noticing this important matter. To ascertain correctly which is the cheapest class of engine now in use, is a problem much too difficult for me to solve; but I will, however, tender such information as I deem reliable.

"The price of a marine engine depends entirely on the class of workmanship. Should a roughly-finished engine and boiler be required, with more painted than polished surfaces, the cost will be reduced in comparison to that of the more highly finished. The fittings also greatly regulate the outlay. Some companies pride themselves on this portion of display, others, again, look on it as an unnecessary expense; so, to draw a correct line of comparison would involve the amalgamation of the many ideas in order to give a fair evidence. I feel confident, however, that marine engines, with boilers and fittings complete, can be produced of certain classes for £70 per horsepower nominal, and the same can be reduced to £50 per horsepower; each price of course being under certain conditions as to terms and workmanship.

"Allusion must now be made to the power, &c. of marine engines. Nominal power is a term used, particularly for commercial purposes. Each maker has his private rule, hence the difference in dimensions in engines of the same class and power. Actual horsepower is defined by the indicator diagram, speed of piston, &c.; the ratio between the nominal and actual power is in some cases low, in others high. The writer has known instances where the nominal power being 1·0, the actual was 6·0; and in others, nominal 1·0, actual 2·123; the average ratio at present is, nominal 1·0, actual 4·0 to 5·0. With reference to the consumption of fuel, there is a great difference in the evidence. Superheating and surface condensation are slowly making progress, and at the same time reducing the consumption of fuel in ratio to the amount of water evaporated or steam used. The average actual horsepower expended per cubic foot of water evaporated is, water being 1·0, actual horsepower 2·635 to 4·0, and doubtless in some cases more. The ratio of fuel consumed in pounds per hour to the actual horsepower per hour expended may be taken as follows:—Engines of ordinary construction, power, 1·0; fuel, 5 to 6. For expansive working-engines, with superheating and surface condensation, thus:—power, 1·0; fuel, 2·50.

64. *Injection and Surface Condensers for Marine Engines.*—In the paper of Mr. Burgh, of which in last par. we gave an abstract, notice was taken of these two forms of condensers. In the "Mechanics' Magazine" there are two articles going pretty fully into the details of those two modes, of which we here give abstracts. That (*a*) under the title of "Injection Condensers" was published in the number for Aug. 25th, 1865; that (*b*) under the title of "Surface Condensers" in the number for Sept. 1st, 1865.

(*a*) *Injection Condensers.*—"Commencing with the injection condenser for *paddle* and *screw-engines.* Air pumps with vertical action are similar in general arrangement; the piston forms a suction and delivery valve alternately, while the remaining valves are located at the top and bottom of the air-pump barrel. The air-pump is not in all cases perpendicular; for large engines, and in vessels of moderate beam, an angular arrangement is preferred. The suction valves are at the bottom of the pump, which is situated outside the condenser. The discharge valves are at the top of the pump, outside or clear of the cover, the air vessel being secured above the valves last alluded to. This description will apply to most arrangements for paddle-wheel engines.

"Our next type of condenser and air-pumps will be that for *screw* engines. In this case we cannot confine ourselves to two or three examples for comparison, as the number of arrangements for the screw engines greatly exceeds that for the paddles. Marine engines for the screw may be said to be of two kinds as regards the principle, viz., direct and return actions. The condensers and air-pumps applicable for *direct-acting* engines are as follows:—The air-pumps are as near the base line as practice will admit, the condenser being situated between the pumps. The suction and delivery valves are under and over the barrel, at each end. The discharge chamber extends on each side of the condenser and at the end of the same, so that actually the discharge water may be said to surround the condensing chamber during its exit. The means for obtaining access to the valves are by doors, those relating to the suction valves at the sides, while the doors for the delivery valves are on the top of the same. Now it will be obvious that both discharge and condensing chambers must be within the inner lines of the air-pumps. The external shape of the condenser in question is that of an hemisphere on a parallelogram; for the end view, the form in plan being square; also the same may be said of the side elevation. . . .

"We have thus far treated of examples relating to direct-acting engines. We propose next to describe the arrangements of condensers and air-pumps for return-acting engines, commonly known as *double piston rods return connecting rod engines.* Our first selection is arranged as follows:—The condensers are placed between the air-pumps, rising centrally above the same to attain cubical capacity. The discharge chamber is located outside the pumps, and is similar in shape to that for condensing. The suction and delivering valves are under and over the pumps at the outsides of the same, access to the valves being attained by doors at the sides of the discharge chambers and pump barrels. The exhaust steam enters the condenser at the top and the injection at the back end of each condenser. The discharge water pipe is secured at the back end of the chamber in the ordinary manner. The space between the condensing and discharge chambers is occupied by the piston and connecting rods, guides, &c.; hence the cause for the arrangement alluded to. The form of the exterior of the present example will be similar to ɯ, the bottom portion being flat. This relates to the end views, the shape in plan and side elevation being square. In some cases the same exterior of condenser, &c., is preserved, but reverse in arrangement. The condensers in this case would be outside the air-pumps, while the discharge chamber would be between the same. The suction valves are inverted at the bottom of the condenser so as to effectually drain the same. The discharge valves are at the sides of the air-pumps, extending the entire width and length of the bottom of the discharge chamber. The exhaust steam, discharge, and injection pipes are all respectively located as in the last examples. In the next arrangement the air-pumps are raised from the base line as much as the crank shaft will admit. The condenser is raised at the front end and extends below for the entire length of the pumps and valve chambers. The suction valves are outside the pumps beyond the guides of the piston rods. The discharge valves are above the pumps, also the chamber above the former. It will be readily understood that in this case the suction valves are greatly below and beyond the air-pump, a fact to which we shall hereafter allude. The shape of the exterior of the example under notice can be more easily conceived than illustrated descriptively; suffice it to say, the discharge chamber is raised centrally above the condenser and pumps, which latter form the base for the former, the plan and side elevation being as in those previously alluded to. . . .

The true principles of injection condensation.—When steam enters the condensing chamber it is in the form of a vapour; on coming in contact with the cooling fluid in the shape of water it condenses; the two amalgamate, or rather reunite; forming a body of water of a higher temperature than that used for injection. Now, it is obvious that the greater the space occupied by the condensed steam the less room for the process of condensation. Hence, it is practically consistent with natural laws to drain the condenser at the same speed as the injection water and steam amalgamate. When the condenser is below the air-pump or at the side of the same, a vacuum must be caused by the bucket, piston, or plunger before the water will rise in the barrel; at the same time a cessation of flow or exit from the condenser must ensue. The present remarks, of course, refer to single and double acting pumps similarly situated. Above the pump is the correct position for the condenser, irrespective of action. The motion of falling bodies causes a vacuum; hence, in the case of gravitation of water, and the same being applied to condensers, a better vacuum is attained than with the ordinary kind. The arrangement we propose for land condensers and pumps, and also for vertical action on board vessels, is as follows:—The condenser should be on the top of the pump, in fact, the top of the latter should be the bottom of the former, the suction valves being inverted so as to effectually drain the condenser. The discharge valves should be at the side of the pump at the top, access being attained to each set of valves by doors suitably arranged. The bottom of the air-pump barrel might be open to the atmosphere or closed, or inserted in a body of water. By this arrangement a perfect action would be attained, owing to the fact that, on the suction valves opening, the gravity of the water would greatly assist its exit, it being remembered that a vacuum is caused above *and below the water* in all cases. The injection also causes a better vacuum by falling direct rather than rising to fall again within the condenser or beyond the rose or splash plate. . .

"Our ideas of what an arrangement for direct and return-action engines should be, are as follow:—For the former class we should prefer the discharge chamber to be centrally situated over the pumps; the condenser located on each side and in front of the discharge chamber. By this arrangement compactness of the valves and pumps would be obtained, while the discharge chamber would be above and between the pumps; hence an air vessel of great capacity would be attained, a matter not to be disregarded. With reference to the arrangements requisite for return-action engines, it must be remembered that in the present examples the piston and connecting rods, with the requisite guides, greatly impair the compact form of the pumps and condensers. We say this remembering that cubical capacity in the hold of the vessel is of great importance. It next becomes necessary to consider which is the most valuable, height or area, in plan. Should the two last examples for return-action engines be adopted, the results would be equal, owing to the different arrangements being alike in principle of action, with the exception that in the latter case the whole is situated between the guides, which perhaps is the better arrangement for accessibility to the working portions requiring adjustment."

(*b.*) *Surface Condensers.*—"To condense steam effectually is to reduce its temperature to a freezing point. This, however, is impracticable with marine engines, and to attain a continual vacuum of 14 lb. on the square inch is hailed as an event worthy of record in the annals of engineering. Surface condensation was in vogue some time back; at its outset it met with many enemies, who to a certain extent prevailed for a time. Latterly, however, the system has been revived, and has met with general favour. In our steam vessels space is of the greatest importance; therefore, for surface condensers the superficial tubular area must be considered; a certain proportion must also be maintained in relation to the quantity of steam passing from the cylinders. To attain the correct amount of cooling surface required, three important facts must be considered,—the heating surface of the boiler, the grade of expansion in the cylinder, and the temperature of the circulating water used. Other important desiderata also enter into the question, viz., correct arrangement of the tubes, and the disposition of the steam and water. Surface condensers as at present arranged may be said to be of two classes, those having *external*, and those with *internal* cooling surfaces. We will first describe the most modern arrangements in practice, and then consider their relative merits. The tubes in one arrangement are disposed longitudinally of the hull in four separate sets, two sets over each other. The steam enters the condenser at right angles with the tubes at the top of the compartment. On the steam coming in contact with the upper external portion of the tubes, partial condensation ensues, and the vapour forming into a liquid passes through or amongst the lower set of tubes; hence, total condensation is attained in due course. The pumps for the circulating water and condensed steam are situated below the tubes in separate compartments. One end of each pump is used for the forcing of the circulating water, and the other end for the discharge of the condensed steam. In order to obtain a correct circulation of the water, the discharge chamber above the valves terminates on a level with the top of the first set of tubes. It is obvious that, on the water passing through the first set in one direction, a contrary action ensues through the upper set, and thus the tubes are continually filled with a certainty, a matter of importance in external surface condensation. The circulating water in the present case enters the supply chamber below the pump at the back end. The suction and delivery valves are under and over the pump at the side of the same. The valves for the condensed steam are opposite to those last alluded to, or at the back end of the condenser. The suction valves are inverted over the pump, and those for the discharge on the same level, but reverse in action. . . .

"The second method of condensing is that where the steam enters the tubes, and the water surrounds them. Condensers of this class are not much varied in arrangement, owing to the fact, that a more direct action is maintained both for the steam and the water. Our remarks apply to two arrangements, perpendicular and horizontal. When the former is adopted, the steam enters the space over the tube plate at the front end, and in some cases at the top. The air pumps and valves are located below the tubes, so as to effectually drain them, assisted, of course, by the gravity of the water or condensed steam. The circulating water is forced amongst the tubes at the bottom of the compartment, and discharged at the top; the pumps in each case being double-acting, and located horizontally. The tubes when horizontally arranged are located transversely of the hull of the ship. In order to ensure a perfect drainage, the tubes are inclined from the front end to the side of the hull. The steam enters the tubes at the front end, passing to the back direct. The pumps are similar to those last alluded to, and alike in principle and action. We have expressed an opinion upon the arrangement of the tubes for given purposes, for external surface condensers. The same holds good for that of the internal kind.

"With reference to *condensation*, further remarks will not be out of place. Let it be assumed that two condensers are arranged alike as to the position of the tubes; the internal and external surfaces, however, are to be operated on by the steam. The impurity of the water in each case is presumed to be the same, so that the chemical action of the steam is alike in both cases, and of course the sediment in either case will be equal. Now it is obvious that the most simple and available means for cleansing should be adopted. It must be remembered that in the one case the steam enters the tubes, while in the other it surrounds them, but the action of condensation is alike in both. Let a vertical position for the tubes be agreed on, it will be found that in each case the sediment collected will be alike in quantity inside and around the tubes, and on the plates, but with this difference of location. In the case of internal condensation the sediment collects mostly on the top plate, while for external condensation the bottom plate receives the most. Next, as to the removal of the sediment. With internal condensation access to the tubes and plates is available without disturbing them; but with external contact the sediment collects inside the plates and outside the tubes; hence both must be disconnected for cleansing. We have thus far proved that, with reference to the steam sediment, internal contact is better than external condensation, cleansing being considered. The sediment from the circulating water depends on its nature and purity. Care should always be taken to strain the water before it enters the pump, although the power thereby will be increased owing to the friction being lessened. Another reason for preferring internal condensation is that the chemical action of the steam does not affect the tube at the lower end. When the tube plate collects the main portion of the sediment from the steam, a corrosion of the tube ensues at the plate, to a greater extent than at any other portion, due, of course, to the increase or accumulation of sediment at that part. Remedies in profusion have been proposed for protecting the tube, but it should be remembered that to ferrule the tube is to injure its conducting powers, and so to affect condensation. It should not be forgotten either that the tube plate is to a certain extent a condensing surface not unworthy of notice, and therefore requiring attention as much as the tube. Surface condensers, as at present arranged in some instances, are fitted with injection pipes and valves, so that, in the event of a fracture or entire corrosion of a tube, the ordinary mode is adopted without stoppage to any extent. Much could be said in relation to the many plans for securing the tubes. In fact, the best method of securing the metals of a railway, and the tubes in the plates of condensers, are alike matters involving similar amounts of varied opinion. We prefer wooden hollow plugs to any other system of fixing. For a good connection affording ready means of renewal, the nut and india-rubber washer is as simple as any."

DIVISION FOURTH.

MOTIVE POWERS OTHER THAN THE STEAM ENGINE—AS AIR ENGINES—GAS ENGINES—WATER POWER.

65. *Condensed air as an auxiliary to steam power.*—"The subject of condensed air," says a writer in the *Mechanics' Magazine*, under date May 19th, 1865, "which is daily becoming more important, is very closely connected with Sir. W. Armstrong's theory of the probable exhaustion of our coal-fields, and the success of the one idea must be as deeply interesting to the engineering mind as the supply of the other necessary of life is precious to our national welfare. The exhaustion of our black Indies, and the consequent decline of our vital power, affect us

both as a commercial people and as a great nation, and any suggestions which tend to economise our resources, or to make us independent of them, are entitled to the consideration of every thinking person. If knowledge is power in one sense, so is coal wealth in another; it is, therefore, our policy no less than our duty to utilise any means at our disposal to husband that wealth. The condensation of the atmosphere appears to offer to our use many of these advantages, and it is our business briefly to draw attention to some of them. The subject under consideration divides itself into two heads:—1. The condensation of the air; 2. The different applications of the air while in a state of condensation.

"In considering the first head of our subject we observe on the one hand that artificial and expensive power is everywhere requisite, and, on the other, that natural and comparatively inexpensive power is in too many instances running to waste. The problem is to utilise this natural and inexpensive power and cause it to take the place of the more costly article. There are many sources of power of this description which will at once occur to the mind. Among others, Sir W. Armstrong mentions mountain torrents and streams as being, if properly managed, capable of producing much useful effect. To these we may add the immense power of those volumes of air in motion which exert their influence over such an extended area, and which equal in their effect an almost illimitable stream of water running by us to no profit for so many months in every year. The power derivable from the waterfall has been the source of an ingenious though complicated invention in France, but the power to be obtained from currents of air by condensing them would only require a very simple mechanical arrangement. As much of this power as is necessary might thus be brought under our control, and turned to any use for which it might be required. It is unnecessary to enter into mechanical details, but it is obvious that there are many localities in our country, such as high lands near the sea, mountains, or elevated table-lands in other places, which would be very suitable to be thus turned into reservoirs of power. The power is going by us, it is for us to avail ourselves of the advantages it offers." The writer concludes by pointing out the advantages of the system as applied to coal cutting, steam ploughing, &c., &c. On the same subject the "Scientific Review" has an able paper—May, 1865—from which we take the following:— "The use of compressed air in the cutting of coal in the pit is likely to be one of its most interesting applications, as it will liberate from very irksome toil, and great danger, a class of men whose occupation is of a most laborious and painful description. Air is forced into a receiver above the surface of the earth by a steam-engine, so as to produce a pressure of about 50 lbs. per square inch; it is thence conveyed into the mine by metal pipes, and from these to the different workings, by india-rubber tubing about one and a half inches in diameter. At each working it sets in action a machine very like a common steam-engine, but running on wheels, and giving motion to a pick or cutter. At the Audsley coal-pit, the shaft down which the metal pipe passes is eighty fathoms deep. These air-engines are found to do the work very rapidly, and to be extremely manageable. When they are used, the coal is obtained in better condition, and there is no danger of the pitmen being crushed by fragments falling from the roof. The condensed air, after it passes from the engine, ventilates the mine; and, during the great expansion it undergoes, lowers the temperature of the atmosphere, which, in ordinary cases, is inconveniently high.

"Compressed air, on a very large scale, is used in the tunnel of Mont Cenis; which, when completed, will be about 7·6 miles in length. At the Bardonêche side, it is compressed by the immense power derived from a column of water more than eighty-four feet in height, and the use of extremely ingenious and effective machinery; and is conveyed through the tunnel by a large iron pipe. At the Modane side, the air is compressed by means of six large water-wheels. The compressed air gives motion to the perforators or chisels of the boring machines—one of the latter being in each division of the tunnel. They are mounted on wheels, which move on tramways, and each of them has about ten perforators, that are capable of acting in all directions. Attached to each perforator is one flexible tube for the compressed air, and another for the water that is injected into the hole at every blow, to clear out the *debris* and cool the point of the instrument. The perforators are, by means of compressed air let *in behind them*, discharged with great rapidity out of tubes, which are not unlike gun-barrels; and they are drawn back by a similar means, but with less force—turning round in the holes during their return. As soon as the chisels have bored holes to the depth of between 32 and 36 inches, they are placed opposite to other points in the rock, where they make similar perforations; and this is repeated about seven or eight times. The boring machine is then moved back; the holes near the centre are first charged with gunpowder and exploded by means of slow matches, which burn at the rate of 24 inches per minute; and, after the smoke has been blown away by jets of compressed air, the other holes also are charged and exploded. The stone and *débris* which have been detached are then removed, and the perforating machine commences its work anew. . . . . . .

"The application of compressed air to musical clocks is a recent and ingenious idea. . . . .

"One of the most interesting of the recent applications of compressed air is to be seen in the pneumatic loom. . . . . Up to the present time, the object has been chiefly to *improve* the 'picker;' the pneumatic loom *gets rid* of it, and thus avoids a large amount of the noise, improves the fabric, and sets aside every limit to velocity, except that dependent on the goodness of the thread. While the common loom makes, ordinarily, only about 180 picks a minute—a greater speed being counterbalanced by a more frequent breakage of the thread—the pneumatic loom, with yarns of the same quality, will, it is said, make about 260, with very few breakages. The saving of power, with the pneumatic loom, appears to be very considerable; for, while the common loom requires a strong man to keep it moving even slowly, the pneumatic can with ease be worked rapidly by the hand. This saving has been calculated at nearly one half; but supposing it to be only one quarter, it would still be, in the aggregate, of immense advantage. It is considered that the increased velocity the pneumatic principle allows would add about 2,800 yards per year to the production of each loom, or nearly a million and a half to that of all those in the United Kingdom.

"The peculiarity of the pneumatic loom consists in the 'pick' or stroke being effected, not by a clumsy imitation of the human arm, but by a jet of compressed air emitted through valves in the shuttle-boxes. The air is condensed by a pump, or even a bellows, and is conveyed to the shuttle-boxes by a flexible tube. It is liberated at the proper time for impelling the shuttle, by a lever, which is acted on by a cog placed on a wheel that is driven by a pinion on the main axle. Among the advantages claimed for this loom is the mathematical precision with which the shuttle is thrown exactly in the right direction; but it strikes us that this part of the apparatus might be rendered, without difficulty, still more certain and exact in its operation. . . . .

"Another application of compressed air consists in raising by means of it weights from mines. The apparatus used for this purpose consists in an iron cylinder, which passes down the shaft —being continued a short distance below its lower extremity, and also a few feet above its upper. Within this works a piston-rod, having a piston at each end, the space between being the receptacle for what is to be raised from the mine. When the apparatus is to be made to ascend, air is, by means of an air-pump, forced down under the lower piston, through a pipe. This raises the pistons; and when the space between them has been unloaded above, a valve is opened below, which causes them to descend; the air which thus escapes from the cylinder serving to ventilate the mine."

66. *Lenoir's Gas Engine.*—This form of motive power has recently attracted great attention, and has been adopted in so many instances—more markedly in Paris and the United States—that a notice of its main peculiarities may be useful here. For this we are indebted to an article in the "Practical Mechanics' Journal for August 1865." "M. Lenoir patented," says the writer, "his original idea of a gas and expanded air engine, in this country, in 1860. His first notion was to admit the air and gas into the working cylinder by means of a slide valve and ports, similar to those of a steam engine; but the slide, in lieu of being contained within a valve chest, was open to the atmosphere and kept tight against the valve faces of the cylinder by adjusting screws. The port which in a steam engine answers the purpose of the exhaust served as the air inlet, being in communication by a nozzle with the atmosphere, and the gas was supplied to one or other of what would otherwise be the steam ports by being let into the hollow chamber of the slide through an opening in the back of the valve; this opening, as the valve reciprocated, was

brought alternately opposite to one or other of two gas nozzles, the cut-off of the gas being effected by the passage of the opening in the back of the valve from one nozzle to the other, both nozzles being fitted into a plate, against which the valve worked gas-tight. The valve was so worked and adjusted as to open the air inlet a little before the gas inlet, and consequently a supply of air was drawn into the cylinder by the piston before the gas entered therein; the air and gas, as stated by the inventor, being made to form distinct strata under the cylinder, in lieu of being mixed together. The object of admitting the air first, was to neutralize the effect of the carbonic acid gas formed in the cylinder by the previous combustion. In this condition, with one half of the cylinder charged, the gas was ignited by an electric spark obtained by the aid of a pair of electrodes at each end of the cylinder in communication with a battery and Rhumkorff coil. The expansion of the air in the cylinder produced by the combustion, by acting on the piston, caused it to traverse the cylinder. The piston rod was connected in the usual manner, by a connecting rod, with the crank shaft of the engine, which also carried eccentrics for working the slide valves; one of these valves we have already referred to; the other, which was situate on the opposite side of the cylinder, was of a similar construction to the first, with the exception that there was no gas inlet orifice through the back of the slide. The ports in communication with this valve were precisely similar to those of an ordinary steam-engine cylinder. The object of the second valve and ports was to serve for the eduction of the foul air and products of combustion after each stroke of the piston.

"The electric current was directed to one or other of the two igniters by a simple form of rotatory commutator, fitted on to the crank-shaft of the engine, and so arranged that the necessary make and break of contact should be produced at the precise moment required. As it was found that the working cylinder was liable to become considerably heated by the ignition of the gas inside it, a water chamber was cast in the cylinder body, and a continual stream of cold water allowed to flow through it. Such were the general features of M. Lenoir's invention in 1860. In 1861 he obtained a second patent for improvements on his former *plans. During* the course of his improvement, M. Lenoir discovered that the admission of the air and gas, in regular and alternate layers or strata inside the cylinder, was a very important feature in the obtainment of a proper and perfect combustion of the gas, and consequent expansion of the air. To insure this result, M. Lenoir very considerably modified the form and general arrangement of the air and gas inlets and valves connected therewith. As in the first arrangement, the inlet slide valve is open to the atmosphere, being kept tight against the cylinder valve face by the pressure against the back of the valve of oblong nozzles cast longitudinally along the side of two vertical cylinders, bolted to the side of the main cylinder, which is placed horizontally. These small cylinders or vessels serve as receivers for the gas just before it enters the main cylinder, a forked gas pipe supplying both receivers simultaneously. One of these gas receivers communicates by an oblong slot or port in its nozzle with one end of the main cylinder, and the other with the opposite end. The slide valve has two rows of small tubes fitted therein, each row of tubes, when brought opposite to the respective slot or opening in the nozzle of the receiver, allowing the gas to pass direct into the main cylinder in a number of small but distinct streams. Between each of these streams of gas a distinct stream of air is allowed to enter through other openings made for that purpose in the valve, and which are in free communication with the atmosphere. In order that the various alternating veins of gas and air may preserve their respective thicknesses and positions whilst traversing the inlet ports of the cylinder, these ports are formed or subdivided into a number of channels by fitting therein what the inventor calls a 'comb,' which consists of a flat plate having a number of raised ridges cast on one side, three of such ridges forming channels or separate passages for the gas and air to pass along as they enter the cylinder. The eduction slide valve on the opposite side of the main cylinder, consists of a sliding plate, having two thoroughfares through it, which are alternately brought opposite to two eduction ports, made at each end of the cylinder (but on the opposite side to the inlet ports), and to the nozzles of two water chambers, which serve to cool the products of combustion as they pass along to the outlet pipes. The cylinder and cylinder covers are kept cool by *water jackets, or spaces* formed therein, through which a constant stream of water is kept flowing. This water, after issuing from the water spaces, is run into a large tank, where it is sufficiently cooled to be used over again, thus economizing greatly the consumption of water.

"The distribution of the electric current is not effected by a rotatory commutator as in the first arrangement, but is accomplished by a reciprocating commutator consisting of a small metal frame, bolted to the bedplate of the engine, and having attached to it the negative wire of a Rhumkorff's apparatus, so that the whole working parts of the engine which are in direct metallic contact with each other, are charged with negative electricity. An insulating plate is fitted into this frame, and upon it are screwed—so as to be in a direct horizontal line with, but insulated from each other—two short metal bars, from each of which a wire leads to one of the igniters. Beneath these short bars is screwed a single bar, of a length equal to the combined length of the short bars; and this bar is in communication with the positive wire of the induction coil. A metal-blade spring is attached to the cross-head of the piston; and this spring, by sliding to and fro longitudinally along the two short bars and the longer bar below, alternately, brings one or the other of the short bars and corresponding igniter, in electrical communication through the long bar with the coil, so that a spark will be produced at the proper time. Each igniter consists of two wires placed in an insulating core, which is screwed into the cylinder covers. One of the two wires is brought into direct communication with the positive wire of the coil at the moment required, in the manner above described; but the other wire is allowed to remain in constant metallic contact with the cylinder, and is, consequently, always charged with negative electricity. The moment the communication is established between the other wire of the igniter and the coil, a spark will necessarily be produced, which ignites the gas in that end of the cylinder. M. Lenoir, in the specification of his second patent, proposes, in some cases, to admit into the working cylinder, in addition to the air, a certain amount of low-pressure steam or moist vapour, or water in the form of a mist or fine spray, so that on the firing of the gas, the steam or vapour will be considerably expanded, and will increase the effect of the engine. We believe, however, that it has not been thought requisite to construct engines on this principle, the effect of the expanded air alone being found amply sufficient for all practical purposes without the additional complications necessary for the carrying out of this idea."

The reader interested in this matter will find a plate illustrative of the details of this engine, and a description of the same in the number of the "Practical Mechanic's Journal" above alluded to.

Modification of the Lenoir Gas-Engine. — Under this title the Mechanics' Magazine, of date Nov. 17th, 1865, has the following:—"A very valuable improvement in the Lenoir gas-engine has been effected by M. Hugon, of Paris. Hitherto, the explosion of the mixture of coal-gas and air employed in these engines has been effected by means of a voltaic spark, but M. Hugon effects it by a contrivance which is at once somewhat cheaper and much more regular in its working. To the slide or other valves regulating the admission of gas and air into the cylinder he attaches little burners, supplied with gas under pressure, and he so arranges that the flame from these burners shall explode the mixture in the cylinder at the proper time. These little jets are blown out by the explosion, but are afterwards relighted by an outer jet, which is kept constantly burning. This simple improvement seems likely to considerably diminish the uncertainty and irregularity which have hitherto characterised the action of the gas-engine."

67. *The Ammonia Carbonic Acid Gas Engines.*—"M. Tellier," says a Report of the Polytechnic Association of the American Institute, given in the *Scientific American*,—"M. Tellier, of France, has recently invented a means of storing and using mechanical power, by condensing ordinary ammoniacal gas to the liquid state, and applying it for propelling omnibusses, and other vehicles, in places where steam power would not be admitted. The conversion of gaseous ammonia into a liquid by pressure, and its application for locomotion is not new, but the mechanical arrangements by M. Tellier embrace several novelties. The small vessel, containing liquid ammonia and gaseous ammonia above it, may be compared to an ordinary steam boiler; when the valve is opened a portion of the gas, having a tension, at 60° F., of about 100 lbs. per square inch, presses against a piston within a

cylinder filled with common air. This movement of the piston transmits power through a crank, and at the same time condenses the air before it in the cylinder. At the completion of this stroke a little water is injected into the cylinder, behind the piston, when the ammonia is instantly absorbed by the water and a vacuum is produced. The pressure behind the piston being thus removed, the compressed air on the other side of it is brought into play; thus the piston comes to its original position and the crank has completed one revolution. After the ammoniacal water has been drawn off the piston is ready to receive another charge of ammonia. It will be perceived that this apparatus would work more steadily if two cylinders were used; M. Tellier proposes to use three. This arrangement, or any other in which a gas passes from the liquid state at a nearly uniform pressure, has many advantages over that employing atmospheric air as a secondary motor. The President then directed attention to

(*b.*) *The New Carbonic Acid Engine.*—"A contrivance for drawing cars on street railways, by means of liquified carbonic acid, is soon to be tried in this city by Dr. Barbour, of Auburn, N. Y. The gas is liquified by a stationary engine, and in that state is kept on the car, in a strong receptacle. The whole apparatus is modelled after the steam engine, but is of much smaller dimensions. After its use the gas escapes from the exhaust into a large gas-proof bag upon the top of the car; when the car returns to the stationary engine the gas is withdrawn from the bag, and again condensed into a liquid, and is thus used over and over. In many particulars carbonic acid is preferable to ammonia. 1. It has at the melting point of ice a tension of 575 lbs. to the square inch, and would occupy only $\frac{1}{16}$ the room required for the ammonia arrangement. 2. It is brought from the gaseous to the liquid state at one operation, by means of the force air-pump driven by steam; while the use of ammonia on Tellier's plan requires a large quantity of water for its absorption, the weight of which increases the amount of power required to draw the car. At the end of the route the ammoniacal water must be subjected to heat, and the gas, thus disengaged, is reduced to a liquid by means of a force pump driven by steam. 3. The statement of Tellier that a vacuum is produced is not strictly true, for *ordinary* ammoniacal water when relieved from atmospheric pressure loses a portion of its ammonia. The tension of the gas in Tellier's cylinder is, however, so greatly reduced as to allow the reaction of the compressed air to carry the piston to its first position. 4. The unavoidable leakage of minute quantities of ammonia would make a car more offensive to the olfactory nerves than the stable. 5. The cost and trouble of preparing carbonic acid is much less than that required to produce ammonia."

68. *Petroleum Engine.*—"Mr. F. H. Wenham, of Clapham," says the "Scientific American," "has patented an invention, which consists of two pistons contained in a cylinder with open ends. The first piston works a crank by means of a connecting rod, the second is disconnected. During the revolution of the crank the second piston follows close to the first by atmospheric pressure until near the termination of the up stroke. They then separate for a short distance, at which time a mixture of gas and an explosive vapour is drawn in between them. When the first piston arrives at the end of the stroke it uncovers a small touch-hole, a flame is drawn in through the side of the cylinder, the gases take fire, and by explosion drive the second piston to the opposite end of the cylinder; here is fixed a cross-bar, through which the flat-rod of the second piston passes, this is now instantly held fast by two wedges driven into the cross-bar against the flat sides of the rod; this, and the wedges may be grooved to increase the grip. A vacuum is formed between the pistons, and the one connected with the crank in approaching the other by atmospheric pressure causes the revolution of the shaft. The piston before again coming into contact drives the products of combustion from between them through an outlet valve in the side of the cylinder. The loose piston is again released by withdrawing the wedges, and follows after the other for the succeeding stroke. The next improvement is for a means of igniting the gaseous mixture. A gas-jet pours directly into the touch-hole in the side of the cylinder. Surrounding the flame of the jet there is a platinum coil to retain heat. There is a similar arrangement round the touch-hole, and both coils remain red-hot whilst the engine is at work, and prevent the flame from being blown out by the force of the explosion through the touch-hole. He gives increased pressure and intensity to the gas by means of a small *pump or bellows.* A further improvement consists in passing

the gas or air through naphtha, petroleum oil, or other volatile liquids, to obtain an inflammable vapour. The receptacle containing the liquid may be heated to assist vaporization."

69. *Lefroy's Fuel Power.*—An article in the "Engineer"—April 7th, 1865—illustrated with a large drawing, gives a description of this, from which we take the following:—"What is called mechanical power is primarily the development of elastic action, and, secondarily, the action, or rather reaction, of gravity, for gravity is the mere tendency to immobility, which, once attained, ceases to be action or movement. In other words, elasticity is a repellant force and gravity is a cohesive force. For practical purposes heat may be considered as the elastic force and cold the condensing or gravitating force. Heat in a steam engine swells water to many times its normal bulk by the condition of steam, and for various reasons it has thus been used as power; but the fact has been disregarded that the fuel itself in the act of burning multiplies its volume manifold in the form of gases, and that if these gases could be compressed or controlled, as steam is, a great result in power would be attained. How to burn the fuel under pressure is the problem to solve, without destroying the vessel containing it. In the case of guns we do burn the fuel under pressure, but explosively, in the form of gunpowder; while in steam cylinders we want to burn it gradually and without burning the metal containing it. This problem Mr. Lefroy is seeking to solve by burning the fuel so as to pass its force into water. . . . .

"The essential and novel features of the system are three, namely, First, the combustion of fuel under an artificially obtained high pressure. Second, the forcing into and through the water contained in the boiler all the gaseous products of the combustion of the fuel. Third, the utilising, for mechanical purposes, the elastic forces which exist in those gaseous products, instead of literally throwing them away, as at present, through the funnel, chimney, grate, and furnace mouth into the atmosphere. The availability to mechanical purposes of these forces (of which the aggregate value exceeds nearly tenfold that of the steam generated by any existing boiler from the same quantity of fuel) being conditional entirely on the fact of the combustion being carried on in a closed vessel.

"The following advantages are claimed by the inventor:—First, a very great diminution of the volume of both furnace and boiler. A saving of 90 or 95 per cent. of this important element of the cost of artificial power may reasonably be anticipated. This great economy is estimated as due to the greater rapidity of the combustion of the fuel, and to the great increase of mechanical power, which will result from the combustion of each unit of fuel. Second, a great reduction in both the prime cost of these, as due to the diminution of their weight and volume, and to the much greater durability of the proposed boiler (which is nowhere approached by the fire) than boilers of any existing form can possibly possess. Third, an economy of both the entire cost (prime) of the funnel or chimney; and, in the case of marine engines, of the space occupied by the funnel, and of the whole sum of inconveniences essentially involved in its presence. Fourth, a greater security against explosion, as due to the fact that no portion of the system which is exposed to the destructive action of the fire sustains any bursting pressure whatever. Fifth, the greater rapidity of getting up steam after, as well as an entire suspension of the combustion of the fuel during, any interval of inaction. Sixth, a great economy in the labour of stoking (which might even be effected by a simple form of pump, as explained in the general observations) and of the health of the stokers, who, so far as their services may be requisite, will be entirely protected from any direct action of the fire. . . . .

"While with very obvious convenience, as far as the matter of the introduction of the fuel into the furnace and all the details of stoking are concerned, and without impairment of its two novel and essential principles, which are, 'the combustion of fuel under high pressure,' and 'the utilising for mechanical purposes the elastic forces of the gases into which the fuel is converted by combustion,' all oils combustible under high pressure, and gases, whether mineral, vegetable, or animal, may be substituted for coal as the fuel in the system above proposed; one or the other of the three following descriptions of fuel, and modes of supplying the same to the furnace, will, under existing conditions, probably be found to be the most economical, namely:—First, petroleum alone, to be pumped in by a simple force pump. *Second, balls of patent fuel,* made of coal dust floating in petroleum, so small that the whole may be treated in a pump as a liquid. Third, balls of similar patent fuel, as exhibited in this engraving, and also floating in petroleum, but of a diameter too large to admit that the petroleum in which they float shall be pumped into the furnace as a liquid.

"With modifications of form specially adapted to each purpose, which will doubtless occur to persons engaged in the respective trades, this system appears to be readily applicable to the following purposes, namely:—First, to the evaporation or distillation of all liquors, syrups, and many other bodies. Second, to the roasting and smelting of ores. Third, to the heating of buildings for any purposes, whether of manufacture, trade, or personal health and comfort, and probably, as compared with existing methods of conducting these operations, with advantages in point of economy, convenience, beauty, and elegance of form, not inferior to those which it is believed to possess when applied solely to the purposes of developing mechanical power. Fourth, to the development of artificial light. Fifth, to the conduct of the combustion of gases and oils, with a view to develop the maximum of both light and heat, producible from the combustion of the same fuel. Sixth, to the manufacture of coal gas for the purpose of illumination, by the introduction of a middle chamber (answering the purpose of an ordinary retort) between the furnace and the boiler, whereby both processes can be carried on simultaneously, and by means of one fire. And such a twofold application of the heat generated evidently will not be confined to the manufacture of gas only, but may be made available to many processes in the arts and manufactures, now carried on as separate operations, which require a high and constant temperature, such as by this system is ensured. The arrangements under this head are shown in a supplementary drawing.

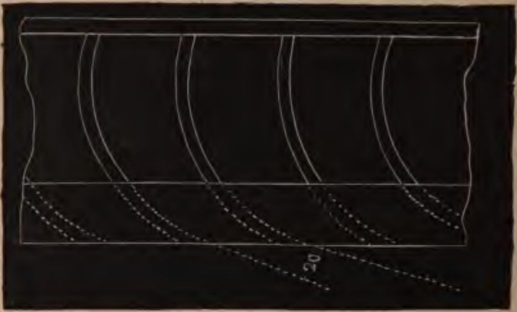
"The novel system above proposed, of conducting under high pressure the combustion of fuel for almost every conceivable purpose, is believed to open a cheering prospect of abolishing the tens or hundreds of thousands of chimneys which now pour into the atmosphere of our large cities those masses of filthy and noxious smoke (that is, of unconsumed combustible matter) which now encompass them, and begrime their populations and buildings; and of reducing by 90 per cent. the expenditure of the fuel requisite for all purposes, whether of mechanical power, of the industrial arts, or of domestic comfort, luxury, and elegance, with more than a proportionate advance in the general comfort and refinement of domestic life, and the health of all classes of our city, and of many classes of our rural populations."

70. *The Heated Air Engine.*—Under this title, the "Mechanics' Magazine," of date December 1st, 1865, has the following. (The article is illustrated by an engraving, not here given):—"This engine, which is of American origin, differs in its mechanical construction and operation from the other hot air engines which have been constructed; as it uses the products of combustion and expansion of the heated air in direct communication with the working piston; the regulating and controlling of it being performed by the agency of improved induction and eduction valves. The other engines have only used the products of combustion to heat the air introduced by pressure into an air chamber or generator, whereby an immense amount of power has been wasted or lost, which might have been rendered available by using it in connection with the expanded atmosphere. The engine is perfectly self-contained; the air-pump, cylinder, and furnace being bolted down on a base or sole plate, and it can be moved into its position and at once started to work, whereby the loss of time incurred where foundations, &c., for boiler and engine have to be put up is entirely saved. Its parts consist of an air-pump, a furnace connected by proper passages with the air-pump; a cylinder, to and from which the heated air is admitted and withdrawn by the valves and their arrangements; the beam, connecting rod, and governor are, as in an ordinary beam engine, for communicating the power to machinery requiring it; and the bed plate or sole piece, on which the whole is bolted and supported.

"The air being drawn into the pump, at the upstroke of its piston, is by its downward motion forced through the passages into the furnace, on its way to which it passes round the lower part of the cylinder to keep it cool, getting gradually heated on its way, and passes under the bottom of the furnace, and enters a passage on one side of it, passing up and entering into the furnace over the burning fuel, where it mixes with the gases and other volatile *products* of combustion; then passes out of the furnace through a proper opening into the valve chest, whence at the right moment, by means of the induction valve, it enters under the piston, forcing it to the end of the stroke, at which moment the induction valve closes, the eduction valve opens, the heated air escapes, and the piston is brought down to the bottom of the cylinder again, by the dead weight of it, assisted by the momentum of the fly wheel and other moving parts. We may add that this engine is to be seen at work at No. 16, Laurence Pountney-lane, City. Having inspected its working we can testify to the efficiency of the arrangement."

71. *Van Dewater's Turbine Water Wheel.*—In the "Scientific American," the following remarks on this form of turbine are given. They are illustrated by four drawings, one of which we give in Fig. 19, namely, a section showing the shape of the buckets.

Fig. 19.



"These wheels are quite celebrated, and are in use in all parts of the country. We have seen testimonials from different parties now using them, who express the greatest confidence in, and satisfaction with them. Mr. Van Dewater says:—

"My experience for upwards of twenty-three years has enabled me to become thoroughly acquainted with all the difficulties that each and every water-wheel of the day is subject to, and I have made effort to avoid them; from my certificates I think that manufacturers and mill-owners will be able to convince themselves of its utility and superiority. My long experience in building turbines has enabled me to construct my buckets so as to gain a maximum speed of the velocity of the water on all their points at the working speed of the wheels.

"I am ready at all times to contract with manufacturers and mill-owners, to construct and set in operation my Improved Jonval Water Wheel, from 3 to 350 horse-power, upon the most reasonable and satisfactory terms. The wheel is highly finished, and the buckets are polished, and so constructed that they can be built of iron or steel. I am willing to warrant my wheel to work up to my table, which yields the most horse power from the amount of water used. The great outlay of building penstock is avoided, and under a fall from 15 to 25 feet the pressure is so great that the floom must waste more or less water in time if the wheel is not located near the upper level of the fall. It can be located at any point, or between two levels of the fall, or set in the bottom of the floom.

"An 18 inch wheel, under 6 feet head, 24 inches of water, makes 189 revolutions per minute at work—giving, according Mr. Van Dewater, 1·81 horse-power; and he says he has yet to learn of a single instance where they have failed to give satisfaction."

72. *On a new Water Engine.*—At a meeting of the Institution of Engineers in Scotland, reported in the "Practical Mechanics' Journal for April 1865," Mr. C. H. L. Fitzwilliams read a paper descriptive of this :—

"In places where a constant supply of water at a high pressure can be easily obtained, as is the case in most large towns. small water engines, for driving light machinery not constantly in use, can be more advantageously used than small steam engines to perform the same work; for instance, for driving organ bellows, small turning lathes, hair-brushing machines, &c. By the simple turning of a tap the engine is started, and the same tap serves also to regulate the speed and the power at which the engine works.

"The cylinder engine and the turbine are the only engines at present used for such purposes.

"I have the honour to lay before you a drawing of a water engine on a new principle, which I hope you will think worthy of your attention.

"In the drawings before you (one only of four given in the

Fig. 20.

'Practical Mechanic's Journal' is here given, Fig. 20), the water enters the engine from the supply pipe at A, presses on the piston at B, driving it round to C, making the drum M take the position of the drum N, as shown in drawing; the shafts, E and E′, being geared together, N takes the position of M, as shown in drawing, after the first half revolution; the water then acts on G′ as before on B, the driving pressure being during one-half of a revolution on the one shaft, and during the other half of the revolution on the other. The water, after it has done its work, is discharged at D. The teeth of the wheels, F and F′, are stepped, to make the movements of the two shafts more equal. G is the casing, H is the cover.

"Three years ago, Professor Weber of Göttingen, in one of his lectures, mentioned that a new sort of air-pump had been invented by a man of the name of Repsold, in Hamburg, and used by him to discover leaks in the system of gas-piping laid down in that town. Weber made a rough sketch of the machine, and explained its theory, showing that the volume of the air passing through the pump during every part of a revolution was constant. Now, it struck me at the time that this machine would make a good water engine, for if it was worked as an engine it would have no dead points, and also the pressure of the water on the driving piston would be constant at all points of a revolution. When I considered the question more fully, I found that my supposition was quite correct.

"In my design of an engine on this plan which you have now before you, the piston surface is 3·75 square inches; the stroke, or its equivalent in this sort of engine, is 12·56 inches. Supposing the machine to work at 1000 revolutions per minute, the piston must travel 1046·66 feet per minute; if the pressure is 40 lbs. per square inch, the total work done by the water is $\frac{40 \times 3{\cdot}75 \times 1046{\cdot}66}{33000} = 4{\cdot}75$ H.P. What the coefficient of efficiency of the engine is I cannot say; it is not easy to calculate, and has not been determined practically. That of a well-constructed turbine, according to Rankine and Delauny, is ·75; though Mr. Schiele says his turbine utilizes ·89 of the power expended. Sir William Armstrong gets by his cylinder engines from ·66 to ·77 per cent. The actual power of the engine would be, I should think, somewhat over 3·5 H.P. If the fall is not more than 30 feet, it cannot matter much where the engine is placed with regard to it. It would be just as efficient if it were placed at the top of the fall, as it would be when placed at the bottom.

"The water moves through the engine in one solid stream, during one half of a revolution down one side, and during the other half down the other. A comparatively small surface of the water comes in contact with the sides of the engine, so the friction cannot be great between either the water and the engine itself, or between the different molecules of the water. The drums ought to fit as well as possible, without touching each other or the casing.

"If the engine has work to do of an irregular nature, the stored force in the column of water in the supply pipe comes into play, and acts in the same way as that stored in a fly-wheel. In the cylinder engine this same latent force is a source of great trouble and waste. Sir W. Armstrong in his hydraulic engine has recourse to relief valves, in the valve casing, allowing water to escape into the exhaust when the pressure, at the turn of the stroke, gets higher than the engine can bear with safety. His engine, when this happens, is said to 'over-run' itself.

"A small rotary water-pressure engine on this plan works well as a water meter, as the same quantity of water must be used for each revolution, so that knowing the number of revolutions made, the quantity of water passed through the machine is also known. I have tried this model as a meter, and found that, although the drums do not fit at all well, it allows very little water to run through it unaccounted for. When running at 2,208 revolutions per minute, the slip was 1·21 per cent. The pressure on the water was about 6 lbs. or 7 lbs. per square inch. I could not try it at any higher speed, as the cock from which I got the water was very small, and could not supply enough to drive the model any quicker. When running at slower speeds, I found the slip to be relatively greater, though the pressure was much less. At first sight one would be led to suppose that the higher the speed, and consequently the pressure, the greater would be the slip, but this is not the case. When running at a very high speed the escape between the drums is much diminished. Directly any water manages to get between them, it is thrown back again, as the surfaces of the drums, between which it tries to pass, are moving quickly in the opposite direction. The engine can be worked as a pump when driven by a pulley off some other engine. A pump made on this plan would possess the advantage over the common centrifugal pump, that it can work at quick or slow speeds with equal efficiency.

"This principle might also, I think, be adopted to advantage in the construction of an exhauster in a gas-work, to facilitate the transportation of the gas from the retorts into the gas-holder, as it can run at a very high speed without fear of its getting out of order and breaking down. I believe a good machine of this sort is very much wanted.

"I think I have now stated the principal uses to which engines made on this principle may be applied, and hope that before long I may have the pleasure to see an engine constructed after my design put to some practical use."

DIVISION FIFTH.

GENERAL MACHINERY—TOOLS.

73. *Engineers' Tools.*—The following article, which we extract from the "Engineer," June 23d, 1865, will appropriately head the present Division of our work. "Although the principle of action may be much the same in most cutting tools, the modes of its application to particular classes of work are, naturally, being constantly extended. When iron was once trued to a flat surface by means of the chisel and the file, the planing machine deservedly ranked, upon its first appearance, as an invention not only of importance, but of no inconsiderable ingenuity. But so accustomed are we now to so many varieties of engineers' tools that it is difficult to fully realise that they are of very recent origin; and so simple and so much a matter of course is their action that it is almost a question in some minds whether they embody any real ingenuity at all. But, even to the most careless as well as to the best observers of mechanical ingenuity, there is a wit, so to speak, in many of the later adaptations of tools to irregular or special work. Until lately the inner surfaces of the rims, between the spokes, of railway wheels were either left rough, as they came from the forge, or trued up with the chisel. The finish was not only imperfect, but the least irregularity in weight, in a wheel going perhaps sixty miles an hour, is a cause of extra disturbance and wear. By a very simple adaptation of the shaping machine the surfaces between the spokes of railway wheels are now finished to a curve, by a tool moving in an arc across the width of the rim. In real simplicity there is scarcely more in this than in any other mode of machine shaping; but the purpose and the machine itself are unique, and whether we say 'a happy idea,' or a 'neat dodge,' we equally express the pleasure which every exhibition of real ingenuity always affords. There is cleverness, too, in the working of planing tools around the curved or oblique edges of armour plates, and there is a distinct satisfaction, known to the mind of every real mechanic (if the mechanics who prefer the term 'engineer' will pardon us), in seeing the edges of a united thickness of 3 ft. of ships' plates

squared at one operation by cutters fixed upon a revolving face plate. The machine for rifling cannon is another form of neat mechanical adaptation, as is that, also, for planing the Whitworth polygonal shot. It only needs new purposes, however, to produce an almost endless variety of equally neat—for we can hardly choose a word which better expresses the idea—of equally neat mechanical combinations in engineers' tools. When engineers were debating—as many of them, perhaps, are still debating—the merits of drilled rivet holes, the multiple drilling machine was brought out. We must own that there is much contradictory rumour as to the real use of this tool, or, in other words, of its being used by those who have it in their works. It is an ingenious machine, in many points, nevertheless. So, too, was the multifarious punching machine, by the late Mr. Richard Roberts. Only one, that now at the Canada Works, at Birkenhead, was ever made. Another, which, when completed, will be the second, is now in progress at the works of the London Engineering and Iron Shipbuilding Company. We shall not now revive the question of drilled *v.* punched rivet holes further than to say that, while Mr. Maynard's experiments, made public a year ago, show an average nett gain of 15 per cent. in the strength of drilled over punched work, others, who are reckoned high authorities, but who have not published their experiments, deny that drilled work has any real advantage whatever. Keeping to our present subject, the machines, both for multiple drilling and for multiple punching, are ingenious and effective. So is the machine for working out the throws of crank axles, while the crank is held down in a fixed position. And there is a neat adaptation of means to ends in the simple gear now used in some, if not in all, locomotive workshops for planing the valve faces of cylinders *in situ.* Many of these machines are not known as they deserve to be, but in an article like the present it would be tedious to describe them, and, we fear, still more tedious to our readers generally to read descriptions of them. Whatever the arrangement of the parts may be, most engineers' tools are employed to alter the surfaces and forms of metals by cutting, either superficially or by deep incision or complete perforation. And in all tools there is either to be effected the movement of the *cutting* tool against the fixed object, or the movement of the object operated upon against the fixed cutting instrument. And the working gear, while it must consist essentially of well-known parts, is variable to an almost infinite extent in its combination. What these variations are our readers are in the habit of seeing frequently illustrated and described in the appropriate pages of *The Engineer*.

"It is hardly necessary to say that, with the increasing substitution of steel for iron, heavier and heavier tools are required. It is something to see a chip 5 in. or 6 in. wide, and nearly $\frac{1}{8}$ inch thick, taken off the edge of an armour plate, at the rate of 15 ft. or 20 ft. per minute, and as quietly as if the plate were of lead instead of iron. With Krupp's steel, and, indeed, most steel, the rate of cut cannot well be much above one-half that usual in iron; and it is an object, therefore, to have as strong tools, and to take as large a cut as possible, in working in such metals, which, on some lines of railway, are now employed exclusively for crank axles, tires, guide bars and piston rods, and the use of which, indeed, is becoming the rule rather than the exception for most of the working parts of locomotive engines.

"For ordinary planing and turning, the action of the tools being invariable in principle, no great change, of course, can be introduced into the details of construction. Many of our readers, members of the Institution of Mechanical Engineers, will have lately received copies of Mr. Fletcher's practical and interesting paper on machine tools, read last year at the Glasgow meeting. It is seldom, indeed, that we get a paper now-a-days, upon machine tools. As the late Mr. Robert Stephenson once said, at a discussion at the Institution of Civil Engineers, upon Mr. Sawyer's paper, they present but little matter for discussion. An engineer is apt to look upon machine tools much as a hard-working man would look upon his own frame. Both would be inclined to say that the object in mind was an ordinance of nature, and that there was nothing to discuss more than there is in the height of Snowdon, or Ben Nevis, or in the flow of the Thames or the tides. A machine tool, however termed, is but an instrument for applying force—and it may be steam force, or water force, or brute force—to the shaping of one of the most obdurate metals known in the arts. It is only in points of detail that engineers' tools *are really interesting*, even to engineers; and the details are tedious of popular discussion chiefly because they are constantly varying."

74. *On Improvements in heavy Tools for General Engineering and Iron Shipbuilding Work.*—A paper (alluded to in the last par.) by Mr. James Fletcher of Manchester, was read before the "Institution of Mechanical Engineers," and fully reported—with numerous illustrations—in the "Engineer," under dates June 23d and 30th, 1865, from which report we take the following:—"During the last thirty years the great rise and progress have taken place in the construction and application of general engineering and iron shipbuilding tools, their manufacture now forming a very important branch of mechanical engineering. Forty-five years ago, at the commencement of the writer's career as a mechanic, tools were of a very rude and primitive description, the lathe and drill being about the only ones then in general use; slide lathes were possessed only by a few persons, being made with great labour and expense, and very inferior in point of workmanship.

"The introduction of the planing machine, however, and its subsequent development, effected an entire change in the manufacture of tools and machinery of every class, giving the means of carrying out with facility many works which had been left unattempted previously as too expensive or impracticable, and opening the way for improvements and invention generally; and in a short time these machines became indispensable in every workshop. The slide lathe became then comparatively easy of manufacture, and, in conjunction with the planing machine and self-acting drill, formed a most important feature in the advancement of engineering work. Still much remained to be effected: a large proportion of work was done by hand, especially the smaller portions of machinery, until slotting and shaping machines were brought into use, and special tools were adapted for all parts where a quantity of work was required to be produced. By the gradual introduction and perfecting of the regulator screw, the wheel-cutting engine, standard gauges, large surface plates, long straight edges, and scraped surfaces, combined with the improved tools, not only was the amount of manual labour considerably diminished, but the work was done more expeditiously, and a *much greater* degree of accuracy was attained, whereby the workmanship in all classes of machinery was remarkably improved and at a great reduction in cost. As engineering skill was brought to bear on schemes which could not previously have been carried out, so were tools enlarged and new ones invented, to meet the exigencies of new works; until engineers and others became really dependent for the accuracy and execution of their work upon the tools that could be employed for the purpose. The steam engine, with all the inventive genius that has been concentrated upon it, would without these tools have still been most imperfect in construction, and would have formed a wide contrast to the engines erected at the present day, in point of excellence of workmanship, durability, and cost. Many instances could be given where tools of unusually large dimensions or the most minute description are indispensable for the execution of the work required.

"The great change which has taken place in the substitution of wrought iron for wood or cast iron, especially in ship and bridge building, is a subject worthy of special attention. In shipbuilding the use of wrought iron has advanced with such rapid strides during the last twenty years as to cause a complete revolution in the trade. The transition was so sudden, and the demand so great, that much difficulty was experienced in procuring a sufficient number of the necessary class of workmen, until those who had previously been employed as shipwrights in building wooden vessels were in a short time enabled, by the assistance of improved tools and appliances, to compete with more practised hands, and to cope easily with the heavy modern work. Improvements in the construction of iron ships were then rapidly developed. New tools were called for and produced, by means of which the work has been materially improved and facilitated; the edges of the plates are now planed to make perfectly fitting joints, and multiple drilling machines are rapidly coming into use for drilling a large number of holes at once in the plates or keel bars.

"Another important feature in connection with improved tools is the direct application of steam power to individual machines, especially those for the purpose of punching and shearing plates or cutting bars, &c., by the combination of a small steam engine with each machine; thus rendering the machines portable, entirely self-contained, and independent of other sources of driving power, and thereby saving in many instances the necessity of running a large engine and quantity of shafting to drive only one or two machines, when pressed for the work upon which they are engaged, and entirely dispensing with shafting and the usual attendant expenses. By this means, and by the use of an underground steam pipe with branches at convenient points, either in workshops or along the sides of docks, these machines may be moved about to any part required, and thus obviate the inconvenience and loss of time in carrying work to and from the machines. Steam pipes of great length are now being used and are found very satisfactory for purposes of this description; and this plan makes a much more convenient and less costly arrangement than shafting, which requires constant attention."

(*a.*) *Lathes.*—"In the earlier construction of the lathe the slide rest was the first great step towards the principle of the slide lathe, and no doubt led to that invention, which was considered impracticable before planing machines were made of sufficient magnitude to plane a lathe bed of even small dimensions. A few slide lathes had indeed been made, the beds of which were composed of a timber framing, covered with iron plates on the upper side to preserve the surface, similar to those which were previously used for the ordinary hand lathes, with the exception that the outer edges of the iron plates were made of suitable shape to form the V's for the carriage to slide upon. It was not, however, until some time after the introduction of the planing machine that, the cost of workmanship being considerably lessened, slide lathes came into general use, and their utility was fully acknowledged and attention directed to their improvement.

"The application of a screw to the slide lathe, so as to render it capable of both sliding and screw cutting, was the next important improvement; and a great amount of time, perseverance, and capital was expended by a few persons in endeavouring to perfect this portion of the lathe. A short screw was first made as accurately as possible, with the rude means then possessed, from which one was cut double the length, by changing the turned bar end for end in the lathe after cutting one half. Subsequently, by following out this principle, screws were capable of being made *of any* length required.

"After this the surfacing motion was introduced; and also the use of a shaft at the back of the lathe, in addition to the regulator screw, for driving the sliding motion by rack and pinion, instead of both the motions of sliding and screw cutting being worked by the screw alone. For it was found that the threads of that portion of the screw nearest the fast headstock, being most in use, were worn thinner than the other parts; and, in consequence, the lathe did not cut a long screw with the degree of accuracy which it otherwise would have done.

"Thus, step by step, improvements were gradually brought forward; the four jaw and universal chucks, and other important appliances, were added, so as to render the lathe applicable to a great variety of work, even cutting spiral grooves in shafts, scrolls in a face plate, skew wheels, and also turning articles of oval, spherical, or other forms. The duplex lathe, with one tool acting in front and the other behind the work, is also found to be a very useful arrangement for sliding long shafts, cast-iron rollers, cylinders, and a great variety of work, where a quantity of the same kind and dimensions has to be turned.

"I may call attention to an improved lathe designed for the purpose of turning long shafts, screws, or other articles. The bed is 40 ft. long, cast in one piece and planed the entire length at once. It is provided with two pairs of headstocks, placed right and left hand, each pair having its own carriage and tool chest, and working entirely independent of the other; the one pair being 15 in. high to the centre, and other 12 in. high. In connection with the larger headstocks is a regular screw, running through the entire length of the bed, by means of which, when the other headstocks are removed, a screw 35½ ft. long may be cut at once. The smaller headstocks, by means of a separate shaft at the back of the lathe, are capable of sliding an article 25 ft. long, and can also, if required, be provided with a screw-cutting arrangement. Thus this lathe possesses the advantages of being used as two lathes for work of an ordinary character, but at the same time a very long shaft may be turned when required. In many workshops a long lathe is an absolute necessity, although the whole length of the bed may not be required many times during the year; and unless some similar arrangement to the one above described is adopted, a large portion of the lathe bed, taking up valuable space, would remain idle and useless the greater portion of the time. Again, in sliding long shafts the two carriages and tools may be in operation at once upon the same piece of work, and thus economise time. The headstocks being placed right and left hand, the loose headstocks are thus able to accommodate each other to the different lengths of work, thereby avoiding the necessity of moving the fast headstock and top cone pulley when any work above half the total length of beds is to be turned.

(*b.*) "*The Planing Machine* is one of the most important tools in use, and has done more towards the advancement and success of engineering work than any other invention, with the exception of the lathe; and has passed through a great number of changes since its first introduction down to the present time.

"In the first planing machines the table was moved by means of a chain winding on a drum, as in the old hand machines. But this mode was found to be very objectionable; the cut was unsteady, and when the tool was suddenly relieved at the end of its cut, the table had a tendency to spring forwards; it was also driven at the same speed both forwards and backwards, and thus a great loss of time was occasioned. This was much improved upon by the use of a rack and pinion, arranged to give a quick return motion, and also afterwards by the screw arrangement. Much difference of opinion has existed as to the relative value of the rack and the screw for driving the table of planing machines. The writer will not, therefore, go into this question further than to state that his own long experience in this class of machines, after having made a large number with both appliances, has led him to the opinion that the rack is decidedly the most preferable mode of driving.

"In some of the earliest planing machines the Vs were made inverted, evidently with the idea of preventing any cuttings that fell upon the wearing surfaces from remaining upon them. They proved, however, to possess no advantage even in this particular, as the finer portions of the cuttings still adhered; and in addition it was found that from the motion of the table the oil by its own gravity would not remain upon the surfaces, and thus cause them to cut and wear away quickly. They were afterwards made an ordinary V shape and found to answer much better, as the V formed a reservoir to contain the oil in a groove at the bottom, from which it was raised at each stroke by the motion of the table and the apparatus attached for that purpose. The Vs have been constructed of different angles and widths of surface; but it is the writer's opinion that at the present time many machines are made with the angle too obtuse, and the surfaces widened to too great an extent. In machines with very shallow Vs taking a heavy cut off a light article with the tools on the uprights, the table is liable to shift sideways, causing the tools to dig into the work and occasion much mischief. Also with very wide Vs the table when making short strokes cannot work the oil up to the top of their surfaces, and thus allows them to cut or gall. The writer has in use a planing machine with a bed 54 ft. long, the Vs of which have only 2 in. of surface on each side, and are planed to an angle of 85 deg. This machine has been working upwards of twenty years, and for the last six years both night and day; it has been employed during the whole of that time upon very heavy work, ranging from five to twenty tons. The Vs are still in good condition, apparently very little worn, and the work the machine does is at the present time perfectly true. The bed is in three parts jointed and bolted together, and the table in two parts; since at the time it was made there was no machine capable of planing a very long piece, and this was considered to be one of the largest then in existence. The writer has also a planing machine made about the same period with a V on one side of the bed and a flat surface on the other, which plan he found was very objectionable, on account of the two surfaces not wearing equally and the oil working off the flat surface.'

"The planing machines were further improved by the use of two tool boxes on the cross slide, and by the application of slide rests or tool boxes fixed upon the uprights, self-acting vertically, for planing articles at right angles to the tools on the cross slide. The reversing tool box is a very ingenious and useful contrivance for planing flat surfaces; but that plan is not so well adapted for general purposes. Planing machines have, like other tools, been specially adapted to a great variety of work, and the writer has made them with different numbers of tools, up to as many as sixteen, all of which were in operation at once.

"*The great changes* which have lately taken place in the manufacture of wrought-iron and steel ordnance, and the revolution they have caused in the construction of vessels of war, have called into requisition a great many alterations and adaptations of the present machines, as well as many entirely new ones. The planing machine especially has been called upon to do work of a very curious and intricate character, namely, that of planing the edges of armour plates to different curves, shapes, or angles. In most cases this has been accomplished by a pattern bar of iron or steel, placed on edge in a small chuck fixed upon the surface of the table, adjustable by set screws, and shaped to the form to which it is required to plane the edge of the plate; as the table travels, this bar, which runs between two circular rollers attached to the under side of the tool slide, moves the tool sideways, according to the amount of curve in the shaper or guide bar, the tool box being disconnected for this purpose from the screw in the cross slide.

(*c.*) "*The Slotting Machine*, of which the engineers in Glasgow can justly boast the heaviest examples, was originally introduced for cutting small wheels, levers, &c., mostly for self-acting mule and loom work; and was afterwards adapted to a great variety of work by the application of a circular table, which was an improvement of the greatest importance, especially in large machines for slotting or shaping large cranks or other similar work; this is now done to such perfection as to require merely draw-filing and polishing to give the work a perfect finish. Many kinds of quick return motions have been employed for the purpose of saving time in the return stroke of the tool, and to give it a regular and steady movement in the cutting direction. Of these the principal are the eccentric wheels, the eccentric motion, and lastly the lever motion, which makes an excellent and steady movement, and is now very much applied to shaping machines.

"One of the large slotting machines made by the writer has a stroke of 3 ft., and the framing is capable of taking in an article 12 ft. diameter; it has compound slides and a self-acting circular table 6 ft. diameter. The ram moves in a vertical slide, which can be raised or lowered to suit the depth of work on the table, so as to form a support to the ram when taking a heavy cut. The motion applied to the tool slide is the lever and connecting rod, arranged so as to gain power and give an almost uniform motion in the cutting direction, and an accelerated speed in the return stroke. . . . . .

"For the purpose of obtaining greater accuracy in dividing out the holes in bridge plates, boiler, or ship plates, a dividing table has been used, and machines have been arranged to punch several holes at once. This was certainly a great improvement upon the old method, since, in addition to the accuracy attained, very much more work was accomplished in the same amount of time. Still the work was not of a satisfactory description; in punching the holes the iron is disturbed or fractured for some little distance round the hole, thus weakening the plate; and, in consequence of the taper which there must necessarily be in all punched holes, the rivets do not thoroughly fill up the space, especially when more than two plates are joined together.

"The faults of punched work above mentioned were so apparent when wrought-iron bridge building became general, that they led to the introduction by Messrs. Cochrane of the multiple drilling machine."

75. *Improved Atmospheric Hammer.*—"This hammer," says a writer in the "Scientific American," "is highly approved of by many of our largest machine makers, and over forty are now in use in different parts of the country. It can be managed with great accuracy, will strike a light or heavy blow, runs rapidly, and is under perfect control. We regard it as a useful machine where die or other work has to be done. We never publish certificates in connection with our illustrations, and are, therefore, obliged to omit those shown us by the manufacturers, who will be happy to furnish them by mail. This hammer works by compressing air in the cylinder, the cylinder itself sliding up and down between guides. The following description will render it intelligible:—

"The air is compressed by a cylinder A, and piston B (see fig. 21). The cylinder moves in the slides, C, by the action of the connecting rod, D, driven from the face plate, E, by belting, in the usual manner. There are two small holes, F, in the cylinder, A; through these the air enters. The whole machinery is carried in a strong iron frame. Now, if we suppose the cylinder to ascend, the air will enter through the holes F, and be compressed as the cylinder goes up. This compression is at the *bottom of the cylinder*, and therefore lifts the hammer mov-

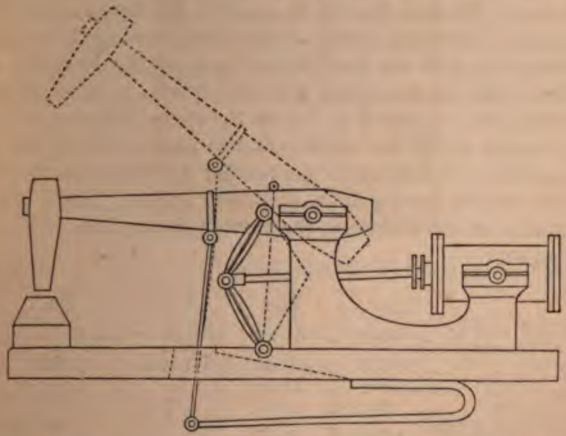
Fig. 21.

ing in the slides. By the time the hammer is lifted the co ing rod arrives at the top centre and commences to de The air then enters above the piston, and, as the cylinder comes down, condenses the volume very highly. This cond air is the force stored up to make the blow, for so soon a connecting rod turns the bottom centre, the confined air ex instantly and thus throws the piston and hammer down great force. This action is repeated at every revolution, an height of the cylinder is altered so as to forge large or small by *lengthening* or shortening the connecting rod. The ha is lifted at the ascending stroke by the compressed air below, as we stated previously, and this also aids the cylinder in compressing the air for the return blow, and it is owing to the rapid action of the two movements that the piston does not fall before it obtains the advantage of the air compressed above it.

"It will be seen that this hammer is exceedingly simple in its construction; there are no valves about it to get out of order, and the packing is exceeding durable and easy working. Both that in the piston and in the cylinder head is made of the cup-leathers used in packing hydraulic rams, and they have run for months without leakage or perceptible wear. The dies are fastened in with keys, and the anvil block, G, is adjusted by another key, so that the dies can be set properly without delay. The speed of the hammer is regulated by an idler pulley, which can be operated by a treadle."

76. *Direct Acting Steam Tilt Hammer.*—"A model," says the "Practical Mechanic's Journal," "of a curious arrangement of direct acting steam tilt hammer (fig. 22), of which we give an engraving, has been recently exhibited before the Society of Arts by the inventor, *Mr. H. Reveley.* The hammer is raised by means of a

Fig. 22.



pair of knee joints, operated upon directly by the piston rod of an oscillating steam engine. In the model exhibited a spring was applied for giving the blow a downward stroke of the hammer, but in practice it is proposed to employ a vacuum piston for this purpose."

77. *On Improvements in Steam Pile Driving Machinery.*—At the Civil and Mechanical Engineers' Society, a paper by Mr. A. H. Lavers on the above subject was read, from which we take the following:—

"It is necessary to state to persons unaccustomed to pile driving, that, in pointing the pile, to prevent as much as possible its going wrong, a centre line should be struck off from end to end, and a template made the shape of the point and then scribed. And to leave a stump point about 2½ in. square, forming a seat for the shoe; the length of the point in timber 14 in. square should be 2 ft. 6 in., and the point of the shoe should be of solid iron, and the four straps 18 in. long, and of iron 2 in. by ⅜ in. or ½ in. nailed on, but this will vary according to the soil they are intended to penetrate. The driving hoop to the head of the pile should be of iron, 4 in. by 1 in., truly fitted and driven on by the ram. The pile is held in position to the uprights by a bolt 1½ in. in diameter, called a toggle bolt, passing through the pile about 2 ft. from the head to the back of the uprights, and there fixed with an iron plate, nut, and screw; a piece of hard wood must also be placed to fill up the space between the uprights, through which the toggle bolt also passes, to keep the pile in its position. I shall omit mentioning anything about screw piles, this subject having been discussed before. I will give a few remarks on the resistance the various descriptions of timber will bear, viz:—

	Oak.	Elm.	Beech.	Fir.
Weight per foot cube in pounds	53	34·56	46	36·87
Tension	11·000	9·500	11·000	11·250
Pressure	3·800	12·00	—	18·00
Specific gravity	·92	·6	·7	·753
Crushing force in tons per square inch	1·7	·57		·86 Riga. ·73 Memel.

"*Fir piling* under a load, will, therefore, sustain as an extreme weight 1800 × 144 = 259,200 lb., or $110\frac{1}{2}$ tons per foot superficial again.

"Memel ·73 tons × 144 = 105·12 tons per feet superficial.
Riga ·86 „ × 144 = 123·8 do. do.

"For practical purposes, we may, however, suppose a case, such as a ram or monkey equal to one ton = 2,240 lb., falling from a height of 6 ft. upon the pile; according to the laws of gravity a body falling from a state of rest acquires an increase of velocity in a second of time equal to $32\frac{1}{6}$ ft., and during that period falls through a space of $16\frac{1}{10}$ ft.; this accelerated velocity is as the square root of the distances, and a falling ram or weight having acquired a velocity 8·085 in the first foot of its descent, and 6 ft. being the height from which a weight of one ton is supposed to fall, we have $\sqrt{6} \times 8{\cdot}05 = 2{\cdot}449 \times 8{\cdot}05 = 19{\cdot}714$ for the velocity in a descent of 6 ft. Then 19·714 × 2240 = 44·159 lb., or nearly twenty tons as the momentum with which the ram impinges on the pile; but in pile driving it (the ram) will average from 15 ft. to 24 ft. per second, friction, batter, and imperfections in machine retarding.

"For the momentum of stroke on the head of pile, multiply weight of ram by velocity in feet per second; but much height will also give momentum of stroke as the square root of the space fallen through. To find the resistance of a pile while driving or when driven:—

w = weight of ram.
p = weight of pile (each in cwt.).
h = height fallen through by ram in inches.
d = descent of pile in one blow.

"Then $\dfrac{w \cdot h^2}{d^2 \cdot w \times p}$ = weight which will just sink the pile.

"When a pile is driven to a state approaching inertion, that is when the ram merely drives the pile regularly about one-quarter or half of an inch, the number of times that the distance driven is contained in the distance of the fall of the ram, divided by 8, is the number of times the weight of the ram that the pile will bear.

"*Example.*—A ram, 6 cwt., falling 20 ft., drives a pile one half inch (20 ft. = 480 half inches, 480 ÷ 8 = 60 × 6 = 360 cwt. = 18 tons). A ram of 8 cwt., falling 12 ft., drives a pile one half inch. Now 12 ft. the fall contains 288 half inches, which, divided by 8, gives 36 cwt. × 8 = 288 cwt. = 14 tons 8 cwt.

"It is important that the fibres of the timber, either as piles or sleepers, should not be subjected to such a force as might in any way lessen or injure their cohesion. An excessive force applied on a fairly driving or driven pile shatters or opens its fibres, breaks the pile probably deep in the ground, or causes its shoe to turn, and it bushes at the foot; the timber will be much injured, oftentimes the pile rendered almost useless, and so porous that springs will rise through it to the surface. It is also an important matter for consideration whether, in the attempt to gain increased supporting power by prolonging the driving a pile to a greater depth into or through (it may be but only a very moderate depth of) hard strata, there may not lie beneath it a much weaker bed, with springs, loose sands, and the other difficulties found. On the Thames frequently there will be found beneath a firm bed of dark clay a crust of flints or stone; if this crust be driven through, a deep bed of sand, fully charged with water, is usually found.

"Timber quickly perishes when subject to alternate changes of wet and dry, but remains sound for a long time under water, particularly in some soils. There is a remarkable example of such preservation in one of the piles of the bridge built by Trajan over the Danube, which, when examined, was found petrified; but this was not the case of more than the thickness of three-quarters of an inch, beyond which the timber was not in any way changed from its ordinary character.

"The ringing engine, I have already mentioned, was used by Perronet at the bridge of Orleans. He made several improvements in pile engines. I believe one of the first steam pile engines was used in America for the construction of railways; by this machine the ram was lifted four or five times a minute, but there was too much weight about it to come into general use.

"This last machine, or ringing engine, has been much improved upon in the common hand pile engine by substituting a ladder instead of the backstay. By framing this ladder, the leaders, and some strong sidestays to a strong bottom frame, and fixing a crab or windlass to this frame, and by a species of balanced catch or nipper, to which the monkey is suspended, meets with a fixed obstruction to its upward passage that bends the nipper downwards, and thus unhooks the monkey, which, falling from a height, strikes the head of the pile, driving it into the ground. The hook or nipper and chain now descend, and the hook, coming in contact with the top of the monkey, locks itself thereto, when it is drawn up again to repeat the operation. Very efficient results are obtained from the machine. Four to six men will, on the average, give one blow in two or three minutes, such blow from 5 ft. to 15 ft. of height. (The appliances generally in use are the ringing engine, hand pile engine, steam crab or winch engine, patent steam pile drivers, and Nasmyth's steam hammer). Steam has been endeavoured to be applied to such machinery in many ways. The simplest takes the form of the crab, being worked by steam either by banding, rocker, &c., or by a steam winch being fixed to the frame of the engine and worked from a portable boiler. Again, there are the patents of Nasmyth's, Sissons and White's, Toshach's and Gilbert's, all good. Nasmyth has applied the principles of a steam hammer to pile driving, and has succeeded in getting sixty to ninety blows per minute, but at a very great cost and extreme complication, cumbrousness, and weight of the pile driver,—all fatal disadvantages in a pile driver.

"Sissons and White's patent is much simpler. To an extra strong framed pile driver a steam winch is fixed, with reversing gear; a small boiler, adjoining pile driver, supplies steam at a high pressure. In the centre of the drum of the winch a toothed or spiked wheel is fixed; these teeth pass freely through the links of a riveted flat-linked chain; this chain is endless, passing over a wheel at top of engine, goes down at back of leaders, and again passes round a small wheel at foot, and returns round the toothed wheel, and soon to the top wheel. To the back of the monkey a frame is fixed by bolts; in this frame two claws or nippers work freely, meeting upwards, the chain passing between these when open. It is evident that by working the winch the chain must revolve by means of the spiked wheel; this being *done the nippers* are by a string pulled to the chain, which they catch, and the monkey is carried up a required distance, when it is set free by a couple of pins or strikers loosely fixed in the back of the leaders; the monkey then falls, and as the chain is constantly revolving the monkey is immediately (the nipper string is pulled) picked up as before. The length of blow is altered by raising or lowering the striker plates. From five to twelve blows per minute can be obtained from this machine; it takes a ram or monkey of from 18 cwt. to 23 cwt. When it is worked with much speed, say to ten blows per minute, the vibration is great, and if worked from the top of a cofferdam it is severely felt; it is simple in its action, and the only part liable to get out of order through wear or fracture is the nippers and frame, but there is a great improvement on the old nippers which has just lately been brought out and patented. The nipper frame is dispensed with altogether, and instead of the catches taking hold of the tops of the outside links, a bolt is pushed into the space between them, that is, into the open link; this bolt is worked by an eccentric fixed in a cell made in the middle of the ram; the eccentric is made to revolve by the lever being drawn downwards by a cord, and the bolt is thus shot into the open link. The striking-off staple is fixed on the outside of the 'leaders,' and the other end of the lever striking against this staple draws the bolt, and the ram falls. This new catch has been tried at a job where many hundreds of piles have been driven, and it answers completely. The piles can be pitched or placed in position by an ordinary chain working alongside the flat chain; the engine can be moved by fastening the end of the rope ahead, passing it over a roller under the winch, and taking a turn round the barrel. The travelling wheels are castors, so that by lifting up each side with a lever the castors can be turned to run on a tramway at any angle. By a different arrangement in the upright framing, piles can be driven in a tideway down to a depth of 30 ft. below the stage on which the machinery stands, the ram driving quite down to the ground. The total weight of the driver and boiler (supplied) is about 6 tons, including the ram and mountings, which are 22 cwt. The bottom framing of the driver is 7 ft. 3 in. square, and the boiler truck 5 ft. 6 in. square; when in work the two are bolted together and travel on the same tramway. To work this pile driver it requires four men, namely, one to drive the winch, one on the stages to shift the striking-off staple, one to attend the pile, and one to work the catch. When the ram has been struck off, the speed of the chain must be reduced by partially cutting off the steam until the catches are again closed. Four of these engines are at work on the Thames Embankment.

"Toshach's pile driver is much upon the same principle, with the difference that the leaders are made wider to allow room for wedge-formed pieces or inclines to slide up and down clear of the back plate for freeing the monkey, as hereafter described, and also that long pins are passed through the endless chain, which has long links, say 12 in., and 1 in. diameter holes to receive them. On the main shaft of the crab is fixed a cast-iron wheel, made of such a shape as to fit into and give motion to an endless pitch chain, which moves behind and as close to the leaders as possible, and round a similar wheel on the top. The chain is made to receive iron pins put through any of the links, and sufficiently wide to carry them up true and square. The pins referred to are made long enough to catch a fork that is attached to and projects from the monkey. The pin, by the motion of the endless chain, carries up the monkey with it, until the chain is forced back, clear of the fork by the wedge pieces, which are adjusted as required on the leaders. Care must be taken to prevent the monkey falling on a pin by keeping the pins wide enough apart. The monkey thus freed falls on the pile, after which another pin is ready to again take it up, and so continue the process until the pile is driven. The wedge pieces referred to are made of iron, and are made to slide up and down the leaders by a winch handle at the bottom, which turns a shaft carrying two spiked wheels, which give motion to two chains that are attached to the inclines or wedge pieces, causing them to rise or fall as required, to regulate the length of the stroke. The fork attached to the monkey may be made to go through it or over it, and to reduce the friction an iron plate back is used instead of wood, to allow the chain to work as close as possible to the leaders; friction rollers are also put on the monkey and back plate. To raise the pile a common chain is fixed to the pitch chain by a shackle or otherwise, and over the top of the framework. The pitch chain being set in motion draws the other along with it, and raises the pile. The advantage gained by this machine is the continual motion of the endless chain, which is always ready to pick up the monkey or ram immediately after it falls on the pile, thereby saving the time usually taken up in pulling down 'nippers' and slack chain. A steam engine may be fixed alongside the crab, which is moved altogether with the machine, or it may be driven with a strap, from a portable, a steam winch, or other engine; but the gearing is so made that, where steam cannot conveniently be applied, handles may be put, and the machine worked by hand. By altering the distance between the pins, and by raising or lowering the bridge, the length of blow is altered. This engine gives from 4 to 8 blows a minute, and does not appear to get out of order."

78. *On Chain Testing Machines.*—Sir William Armstrong read a paper on this subject before the British Association, which held its meeting at Birmingham, of which the following is an abstract as given in the "Civil Engineer and Architect's Journal:"—"The engineering firm of which I am a member having been intrusted with the construction of the apparatus for testing chain cables and anchors, lately established at Birkenhead by the Mersey Harbour Trustees, had occasion to enter into a very careful consideration of the conditions requisite for effecting the operation in the best possible manner. As public attention has been forcibly directed of late to the importance of more accurate methods of testing chains and anchors, a few observations on the subject of the Birkenhead machine will not at the present moment be mistimed.

"The most important consideration in the construction of a chain testing machine is to obtain an accurate indication of the strain upon the chain. The hydraulic press has been for many years the appliance universally employed for exerting the strain, and nothing can be better fitted for the purpose; but the methods of determining the amount of the strain have been extremely imperfect. Most commonly the strain has been estimated by the indications of a mitred valve pressed down by a lever and weight. The impossibility, however, of restricting the tightening surface of the valve to a definite annular line, so as to ex[illegible]e any variation of area, rendered this mode of indication highly delusive; so much so indeed, that the attendants generally paid more regard to the indication afforded by the crackling of the scale on the surface of the iron than to the amount of load upon the valve. By substituting a loaded plunger for a loaded valve, the uncertainty arising from variability of surface is obviated, but a plunger requires a packing to make it watertight, and the effect of the friction of this packing has to be considered in relation to the friction of the press. A plunger without friction would give untrue indications of the strain unless the press were also without friction; but friction cannot be avoided in the press, and therefore friction becomes a necessary element of accuracy in an indicating plunger. To make this more apparent, it is only necessary to consider that in the press the friction of the packing lessens the tension exerted on the chain; while in the case of the indicator the friction of the packing lessens the weight necessary to indicate the pressure. If, therefore, these two frictions be in harmony, the load on the indicator will be diminished in the same proportion as the tension on the chain, and thus a correct indiction of the strain upon the chain will be obtained.

"The proper and usual packing for the hydraulic press is a cupped leather; but as the lip of the leather is pressed against the surface of the ram by the action of the water, the amount of its friction varies directly as the pressure. It is therefore necessary that the indicating plunger should also be packed with a cupped leather, in order that its friction may likewise vary directly as the pressure. But as the ratio of circumference to area is very much greater in the small ram of the indicator than in the large ram of the press, it is obvious that with similar leathers the relative friction would be widely different in the two cases. The friction may however be brought to a proper adjustment by reducing the breadth of the lip in the leather of the indicator until its friction is in unison with that of the press leather. This adjustment should be made when the press ram and the indicator plunger are both perfectly clean and free from any lubricating substance, and in no subsequent use of the machine should either oil or grease be applied to these parts. The effect of employing a lubricator is to diminish the friction in the first instance, but afterwards to increase it, because the unctuous character of the lubricant is soon exchanged for a stickiness, which produces an opposite effect. In fact, when grease or oil is used, the frictions become so irregular as to render impossible an accurate correspondence between the press and the indicator.

"There is another desideratum in the testing of chains, which requires a further elaboration of the indicating apparatus. When a chain breaks in the test, it is desirable to show, not only that it failed to bear the full test strain, but also what was the amount of strain exerted at the moment of fracture. In the case of the Birkenhead machine, various indicators upon the principle of those commonly used for steam pressure were tried, for the purpose of effecting this latter object, but none of them gave satisfactory results. An apparatus was therefore designed for this object, which has since come into very general use, under the name of the Pendulum Indicator. In this apparatus the pressure upon the indicating plunger is exhibited by the travel of a pendulum through a graduated arc. The movement is communicated from the plunger to the pendulum, through the medium of a compound lever. When a chain breaks, the pendulum falls back until stopped by a ratchet, but leaves a marker at the exact point on the scale attained by the pendulum at the moment of rupture.

"I have hitherto spoken of friction only in reference to the packing of the apparatus. This friction, as I have already stated, varies with the pressure, but there is also the constant friction due to the weight of the moving parts to consider. If the machine be used exclusively for high strains in relation to its weight this constant friction will be unimportant; but if a heavy machine be used for testing light chains, a considerable element of error will be introduced, unless a proportionate friction of the same constant character be added to the indicator. Still, however, it is better that very heavy machines should not be used for testing light chains, unless they be constructed with more than one press to act separately for light chains, and conjointly for heavy chains. With this view the Birkenhead machine has three presses, the centre one being used alone for light strains, and the three acting in concert when great strains are to be exerted.

"Although an hydraulic indicator, properly constructed and correctly adjusted in regard to its friction, may be safely relied upon as indicating with sufficient precision the strain exerted by the machine, yet for the purpose of ascertaining in the first instance when correct adjustment has been attained, and also of detecting any discrepancy which may subsequently arise from dirt upon the ram or plunger, or from any other cause producing irregular friction, it is necessary that every machine should be provided with a lever indicator, to which the chain may be directly applied, and the strain ascertained by the lifting of a weight. Such an apparatus requires to be accurately fitted with knife-edge bearings in order to afford delicate indications, but, as these are liable to deterioration by too frequent use, it is better to reserve the lever apparatus as a standard of reference for adjusting the hydraulic indicator, which is not liable to deterioration by use. It is not necessary that the lever indicator should range as high as the hydraulic indicator, for if the two indicators register alike through a sufficient series of the lower strains, no discrepancy would be manifested if the comparison were carried to the highest powers of the machine.

"I may here mention that nothing so soon deteriorates the lever apparatus as inadequate length of the knife-edges in relation to the strain upon them. The conclusion arrived at in the Elswick Works is, that not less than one inch length of edge should be allowed to every five tons of strain upon the bearing.

"In the arrangement of a public chain testing establishment it is desirable that the apparatus for the various operations should be placed in such succession as will allow the chains to move from process to process without any retrogression. The Birkenhead chain testing establishment commences with a store-room for the reception of unproved chains. From the store each chain is dragged by a steam power capstan through an opening in the partition-wall on to the testing-bench of the machine. It is there made fast at the one end to the press, and at the other to a cross-head supported on live rollers, which cross-head may either abut against a stop or be connected with the lever indicator. After the chain has been proved it is dragged by a second capstan directly forward in the same line into the examining room, and there stretched upon one of the benches, where it undergoes a close inspection. If found perfect it is then hauled forward by a third capstan through the heating oven and blacking trough, and is thence passed complete into the delivery store at the opposite end of the establishment. The course of the chain being thus in one straight line, it is necessary to carry it over the machinery at each end of the testing-bench, and to accomplish this a channel of wrought-iron is fixed over the machinery to support the chain in its passage. Should the chain fail in the test, or be found defective on examination, it is drawn off by one of the capstans to smiths' fires placed on the floor of the examining room, and, after repair, is again hauled to the testing-bench for a second proof. For the convenience of handling heavy chains at the smiths' fires an hydraulic crane is connected with each fire. Between the testing and examining rooms there is an intermediate room called the indicator room, in which the lever and hydraulic indicators are placed, and the valves of the apparatus manipulated by an attendant in view of the indicators. Anchors are received into the same store-room as the chains, and the usual appliances are provided for fixing them in the test. Over-head cranes are employed for lifting the anchors as well as for lifting the chains in the two stores. There are two testing machines in the establishment, fixed at opposite sides of the room. These are similarly arranged in every respect, but one of them is adapted to test up to a strain of 200 tons, and the other to 300 tons. The hydraulic pressure is supplied from a neighbouring accumulator used for a system of hydraulic machinery at work in the adjacent dock.

"As the general practice is to make chain cable in lengths of fifteen fathoms, the Birkenhead machines are adapted for that length. The Board of Trade have recently fixed upon that length as the limit of length of chain to be tested at one time. The propriety of their so doing has been called in question, but I may state that it is the opinion of those persons who have the management of the Birkenhead machines, that no advantage of any kind would be gained by testing chains in greater lengths. If there is to be a limit it is clear that such limit is best fixed at the length at which chains are usually made.

"There is besides a positive objection to exceeding that limit, because a greater length than fifteen fathoms cannot be tested without the use of intermediate supports, which, whether they be slides or rollers, are objectionable, as being liable to produce variations of strains in different parts of the chain. Another objection to permitting indefinite lengths of chain to be tested at one time arises out of the stretch to which chains are subject in testing. This stretch occasionally amounts to five feet in fifteen fathoms, and if that length of chain were greatly exceeded it would involve a press of very inconvenient length, or necessitate taking repeated holds of the chain, which would be highly objectionable. I think, therefore, that the Board of Trade have acted wisely in imposing a limit, and in fixing that limit at fifteen fathoms."

DIVISION SIXTH.

MECHANICAL APPLIANCES.

79. *Screw Threads.*—A special Committee of the Frankin Institute (United States), was recently appointed to investigate the subject of a "uniform system of screw threads," and the following is their report:—"That in the course of their investigations they have become more deeply impressed with the necessity of some acknowledged standard, the varieties of threads in use being much greater than they had supposed possible; in fact the difficulty of obtaining the exact pitch of a thread not a multiple or sub-multiple of the inch measure is sometimes a matter of extreme embarrassment.

"Such a state of things must evidently be prejudicial to the best interests of the whole country, a great and unnecessary waste is its certain consequence, for, not only must the various parts of new machinery be adjusted to each other in place of being interchangeable, but no adequate provision can be made for repairs, and a costly variety of screwing apparatus becomes a necessity. It may reasonably be hoped that should a uniformity of practice result from the efforts and investigations now undertaken, the advantages flowing from it will be so manifest as to induce reform in other particulars of scarcely less importance.

"Your committee have held numerous meetings for the purpose of considering the various conditions required in any system which they could recommend for adoption. Strength, durability, *with reference to wear from* constant use and ease of construction, would seem to be the principal requisites in any general system, for, although in many cases, as, for instance, when a square thread is used, the strength of the thread or bolt are both sacrificed for the sake of securing some other advantage, yet all such have been considered as special cases, not affecting the general inquiry. With this in view, your committee decided that threads having their sides at an angle to each other must necessarily more nearly fulfil the first condition than any other form; but what this angle should be must be governed by a variety of considerations, for it is clear that if the two sides start from the same point at the top, the greater the angle contained between them the greater will be the strength of the bolt; on the other hand, the greater this angle, supposing the apex of the thread to be over the centre of its base, the greater will be the tendency to burst the nut, and the greater the friction between the nut and the bolt, so that if carried to excess the bolt would be broken by torsional strain rather than by a strain in the direction of its length. If, however, we should make one side of the thread perpendicular to the axis of the bolt, and the other at angle to the first, we should obtain the greatest amount of strength, together with the least frictional resistance; but we should have a thread only suitable for supporting strains in one direction, and constant care would be requisite to cut the thread in the nut in the proper direction to correspond with the bolt; we have consequently classed this form as exceptional, and decided that the two sides should be set at an angle to each other and form equal angles with the base.

"The general form of the thread having been determined upon the above considerations, the angle which the sides should bear to each other has been fixed at 60 deg., not only because this seems to fulfil the conditions of least frictional resistance, combined with the greatest strength, but because it is an angle more readily obtained than any other, and it is also in more general use. As this form is in common use almost to the exclusion of any other, your committee have carefully weighed its advantages and disadvantages before deciding to recommend any modification of it. It cannot be doubted that the soft thread offers us the simplest form, and that its general adoption would require no *special tools* for its construction; but its liability to accident, always great, becomes a serious matter upon large bolts, while the small amount of strength at the sharp top is a strong inducement to sacrifice some of it for the sake of better protection to the remainder; while this conclusion is reached it is at once evident a corresponding space may be filled up in the bottom of the thread, and thus give an increased strength to the bolt, which may compensate for the reduction in strength and wearing surface upon the thread. It is also clear that such a modification, by avoiding the fine points and angles in the tools of construction, will increase their durability; all of which being admitted, the question comes up what form shall be given to the top and bottom of the thread? for it is evident one should be the converse of the other. It being admitted that the sharp thread can be made interchangeable more readily than any other, it is clear that this advantage would not be impaired if we should stop cutting out the space before we had made the thread full or sharp, but to give the same shape at the bottom of the thread would require that a similar quantity should be taken off the point of the cutting tool, thus necessitating the use of some instrument capable of measuring the required amount, but when this is done the thread having a flat top and bottom can be quite as readily formed as if it was sharp. A very slight examination sufficed to satisfy us that in point of construction the rounded top and bottom presents much greater difficulties, in fact all taps and screws that are chased or cut in a lathe required to be finished or rounded by a second process. As the radius of the curve to form this must vary for every thread it will be impossible to make one gauge to answer for all sizes, and very difficult, in fact impossible, without special tools, to shape it correctly for one.

"Your committee are of opinion that the introduction of a uniform system would be greatly facilitated by the adoption of such a form of thread as would enable any intelligent mechanic to construct it without any special tools, or if any are necessary, that they shall be as few and as simple as possible, so that although the round top and bottom presents some advantages when it is perfectly made, as increased strength to the thread and the best form to the cutting tools, yet we have considered that these are more than compensated by ease of construction, the certainty of fit, and increased wearing surface offered by the flat top and bottom, and therefore recommend its adoption. The amount of flat to be taken off should be as small as possible, and only sufficient to protect the thread; for this purpose one-eighth of the pitch would seem to be ample, and this will leave three-fourths of the pitch for bearing surface. The considerations governing the pitch are so various that their discussion has consumed much time.

"As in every instance the threads now in use are stronger than their bolts, it became a question whether a finer scale would not be an advantage; it is possible that if the use of the screw thread was confined to wrought iron or brass such a conclusion might have been reached, but as cast iron enters so largely into all engineering work it was believed finer threads than those in general use might not be found an improvement, particularly when it was considered that, so far as the vertical height of thread and strength of bolt are concerned, the adoption of a flat top and bottom thread was equivalent to decreasing the pitch of a sharp thread 25 per cent., or what is the same thing, increasing the number of threads per inch 33 per cent. If finer threads were adopted they would require also greater exactitude than at present exists in the machinery of construction, to avoid the liability of overriding, and the wearing surface would be diminished; moreover, we are of opinion that the average practice of the mechanical world would probably be found better adapted to the general want than any proportions founded upon theory alone. We have taken some pains to ascertain what the proportions in use are, and submit the following as being in our judgment a fair average, viz.:—

Diam. of bolt	¼	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1	1⅛	1¼
Threads per in.......	20	18	16	14	13	12	11	10	9	8	7	7
Diam. of bolt	1⅜	1½	1⅝	1¾	1⅞	2	2¼	2½	2¾	3	3¼	3½
Threads per in.......	6	6	5½	5	5	4½	4½	4	4	3½	3½	3¼
Diam. of bolt	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	—	—
Threads per in.......	3	3	2⅞	2¾	2⅝	2½	2½	2⅜	2⅜	2¼	—	—

"The proportions for bolt heads and nuts, as given in most of our books of reference, are believed to be larger than necessary, and all are tabulated, necessitating constant reference. A simple formula would probably induce a uniform practice, but as most of the sizes in common use are made by machinery and also by hand, it is believed the bolt-head and nut for finished work should be made somewhat smaller than for rough, to avoid the confusion that would ensue if the necessary allowance for dressing should be made upon work intended for finishing.

"In conclusion, therefore, your committee offer the following:—

"Resolved, That the Franklin Institute of the State of Pennsylvania recommend for general adoption by American engineers the following forms and proportions for screw threads, bolt-heads, and nuts, viz:—

"That screw threads shall be formed with straight sides at an angle to each other of 60 deg., having a flat surface at the top and bottom equal to one-eighth of the pitch. The pitch shall be as in the preceding table.

"The distance between the parallel sides of a bolt-head and nut for a rough bolt shall be equal to one and a-half diameters of the bolt, plus one-eighth of an inch. The thickness of the heads for a rough bolt shall be equal to one-half the distance between its parallel sides. The thickness of the nut shall be equal to the diameter of the bolt. The thickness of the head for a finished bolt shall be equal to the thickness of the nut. The distance between the parallel sides of a bolt-head and nut, and the thickness of the nut shall be one-sixteenth of an inch less for finished work than for rough."

80. *Drills, Chucks, &c.*—We take the following batch of notes and illustrations from the "Scientific American."

(*a.*) *Standard Twist Drill.*—"There is no tool more indispensable in a machine shop than the drill, yet, strange as it may seem, very few persons take much pains in making one properly, or using it right when made. In half the machine shops in the country, drills lie around on the floor, or are left sticking in window corners where no one can find them. They are also altered at will by any person who is too lazy to look for the proper size; they are improperly ground, and, in short, ill used in so many ways that great delay and loss is the result.

"The Manhattan Fire-arms Company, of Newark, N. J., have, at great expenditure of time and money, perfected a system for manufacturing twist drills for the trade, and a sample of them is shown herewith. As a specimen of workmanship these drills have been greatly admired by all mechanics, and as tools are unequalled. We have had an opportunity of seeing these drills at work, and they certainly cut to perfection. They feed easily and without straining through the work, and leave a round, true hole from end to end.

" These drills are all turned from shank to point in a turning lathe, and milled out in the grooves by a peculiar machine invented by Mr. Arnold, of the Manhattan Fire Arms Co.; they are of standard sizes, varying by 32ds of an inch, from ⅜ths up to 1¼ inch, so that a hole of any known size can be made with the set; any such hole drilled to-day will fit the same work years *hence.* Machinists will see the great advantage resulting from

Fig. 23.

this feature. They are tempered up to the end of the twist; and one may be run into the shank without withdrawing it from the work to clear the chips.

"Accompanying these drills are sockets, like that shown by the side of the tool illustrated. These are to be fitted in the machine the drills are to be used in, and may be planed square on the blank end or turned taper, for which purpose a plug centre, C, fig. 23, is fitted in and a centre left in the other. The shank of the drill fits in the socket, and the flattened end, A, is held by the keyway, B, in the socket, so that the tool cannot turn; a key driven into this keyway loosens the drill, so that it can be taken out.

"The advantages to be derived from the use of these drills over those ordinarily made are very great: they are always ready for use; any size can be found in the set without altering; they require no dressing, and when properly used will last for years. They are, withal, sold remarkably cheap, much lower, in fact, than they could be made by individuals. They are about twelve inches long, and will drill from seven to nine inches deep; they are made of the best cast-steel, and are, in all respects, first-class goods. They are now in use in the United States Navy Yard, at Brooklyn, and all over the country, by our largest manufacturers.

"For small metal workers, such as model makers, watch and clock makers and dentists the Company make drills of Stubb's steel wire, with straight shanks of all sizes, from No. 1 to 60, which is about 1-32d of an inch."

(*b.*) *Smith's Rivet.*—"In riveting with the common solid-end rivet, it is a common experience, even with the greatest care, to have the rivet 'cant' over and spring the whole job out of shape. It is also common for a mechanic or other person to strike

Fig. 24.

from five to twenty-five blows before he can form a proper head, or clinch, on a rivet, even under the most favourable circumstances; and also when riveting on leather or other soft material, to have the rivet 'dance round' so as to render it almost impossible to form a head at all. All these difficulties are entirely obviated by this improvement, which consists in countersinking the end of a rivet, as shown, so that when this rivet is struck with a stunt punch, or set or squeezed with an eyelet nipper or other suitable tool, the outer edge will easily turn over so as to form a handsome and substantial head, as compared with the bad jobs which frequently disfigure all kinds of articles on which rivets are used.

"The improvement is applicable to all kinds and sizes of rivets; the countersink can be made of any required depth, and, in the opinion of experts, with very slight alteration in the common rivet machine, be made as cheaply and quick as common rivets are now made."

(c.) *New Chuck for Wood or Metal.*—"Several kinds of chucks are employed for holding work between two centres; for wood, prong chucks or square hold are the most common; for metal, dogs are usually employed; the disadvantage of the above-named chucks for wood is, that the work frequently gets out of centre, when any pressure is used, and it cannot be taken on and off for examination without a risk of missing the centre, when replaced.

"The disadvantage in using dogs, when turning metal, is the necessity of turning the work end for end, which requires the dogs to be shifted—when you wish to turn a cylinder, for instance, or when you wish to file a cylinder on the lathe; and another nuisance of dogs is, the catching of the tool or fingers against the projecting points of the dogs.

"To obviate these inconveniences, I invented a very simple contrivance for holding work between two centres, which is equally applicable to wood or any kind of metal, and the same chuck will hold as firm as a vise a piece of wood or metal half an inch or even twelve inches in diameter. It, moreover, enables the tool of the slide rest, or the hand tool, to pass over the whole length of the work, without turning it end for end; and you can take the work off fifty times and replace it with perfect accuracy.

"This chuck is merely a short cylinder of brass or of iron, *which* screws on to the lathe head with a steel point projecting from the centre of the other end, and three steel points at a short distance from this centre point, but not projecting quite as far out. These three points are equidistant from each other and from the centre point. The projection is about one-quarter of an inch, more or less, according to the nature of the work.

"Fig. 25 shows the face of the chuck with four points projecting. Fig. 26 shows a side view of the chuck.

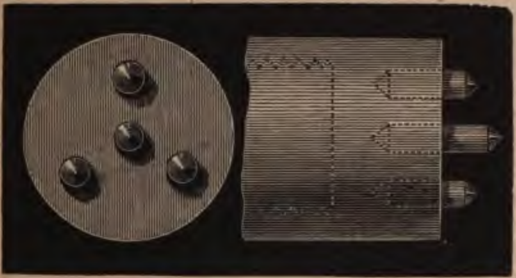


Fig. 25. Fig. 26.

"To make this chuck I drill four holes in the face of it, each about half an inch deep, with a drill corresponding with any size of Stubb's steel wire—one of my chucks is drilled to No. 15, another to 22. I then cut off three pieces of Stubb's steel wire of one size smaller than the holes drilled, and point each one on the lathe, and dip the blunt ends into melted tin after dipping them into muriate of zinc. I heat the chuck on a stove, drop into each hole a little muriate of zinc, and then, with a pair of pincers, put in the steel wires, with the points outward; and when cold the chuck is finished. To use it, drill a centre hole in each end of the work to be turned, with the same drill employed to make the four holes; put the centre point of the chuck into the centre hole of the work, give it a tap with a mallet, and you will have three marks, which will enable you to drill the other three holes in the work, with the same drill.

"These four points, when inserted into the piece to be turned, and when the other end of the piece is held by the point of the puppet head of the lathe, will keep it as firm as if held by a vise, and *it can be taken* off and replaced without regard to which of the three outer points is inserted—for if drilled equidistant, all will fit the work.

"A bar of metal, in which the four holes have been drilled, can be used up until within one-fourth of an inch of the end, and once the chucks are made and the proper drill at hand, it will be found as easy to mark and drill the four holes in the work as to adjust and screw up a pair of dogs, especially if you have several pieces of metal or hard wood to turn.

"I have found—equally with others to whom I have shown my chucks—so much comfort in the use of them, that I freely impart to any mechanic the knowledge how to make this chuck, and the right to use it."

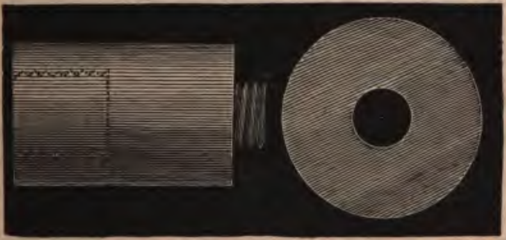
(*d.*) *Chuck to hold Sheet Metal, &c.*—"To turn a thin piece of sheet brass circular, and then to mill its edge, requires time and skill; first, to fasten the uneven piece of brass plate to a wooden chuck by means of screws, in order to turn a circular disk; and, secondly, to fasten that disk between points and a centre, to hold it true and firm during the time needed to mill its edge. Unless great care be taken, the sheet bars will be indented by the points and the centre-point. To obviate these difficulties, I adopt a very simple and quick mode of fastening the metal plate to a chuck.

"Some of your readers may suggest that the plate could be secured by shellac or cement. This plan is the true principle, but the slightest blow would detach the plate and spoil the work. If, however, you use solder as a cement, the adhesion is perfect; and by the following plan, in a few minutes, the plate can be fixed so firmly to the chuck that no blow or jar will affect it.

"As I have found old hands at the lathe entirely ignorant of the process of soft soldering, and as I have laboured for years under the same disadvantage, it may interest some of your young subscribers to know how to attach two pieces of metal in a few seconds. This is effected by placing on each piece, with a leather or small brush, a small quantity of muriate of zinc, and then holding each piece over a spirit lamp—taking care not to inhale the former—and when it boils rub the plate with a thin stick of pure tin or solder; I prefer tin, which I melt in a ladle, throw *out with* a jerk on a metal or stone slab, so as to form a sheet when cold, and then cut into stripes a little larger than an ordinary match. I, however, prefer drawing the tin into wire of different thicknesses, and using it in that state. Any one can make the muriate of zinc by filling an ale glass one third full with muriatic acid, and adding pieces of zinc (in the open air) until it will disolve no more, then pour it off clear. As an experiment for the learner, let him heat a cent by a spirit lamp, placing a drop of muriate of zinc on it, and then rubbing a small quantity of tin on it, while the cent is held by a pair of pincers; then take a copper tack, dip the head in muriate of zinc, and place the head on the middle of the cent, which is still held by the pincers over the lamp; in an instant the head of the tack will become turned, and when both are cool press it with the foot into the floor. The first person who sees the cent on the floor will try to pick it up, and he will enjoy a laugh at the other's expense, and, at the same time, have taken the first lesson in soldering.

"But to return to my chuck, which I call my 'solder chuck.' It would answer to heat any thin brass chuck and tin its face, then to heat the sheet brass you wish to turn round, and to tin it also; placing the two tinned surfaces together, you heat them and let them get cool, with a weight pressing them together until cold; but this would consume too much time and alcohol. I therefore make my chucks of brass or iron, with a steel male screw, projecting not quite one-fourth of an inch beyond the face of the chucks. (Fig. 27.)

Fig. 27.



"I make several washers of brass, one-fourth inch thick, and tap them so that they screw accurately on to the male screw;

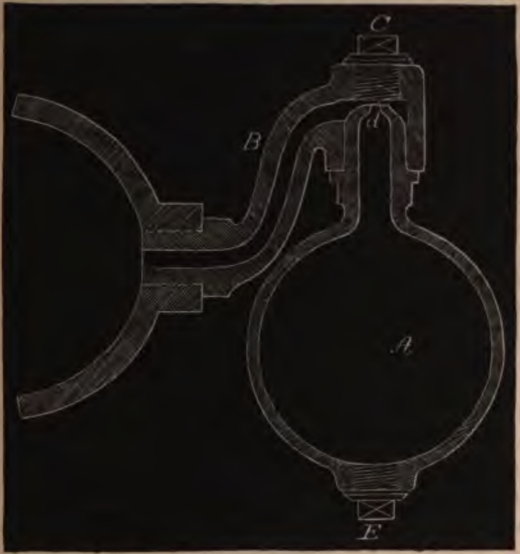
they are of different diameters, to support smaller or larger pieces of brass plate, according to the diameter of sizes I may wish to turn. One side of these washers I tin by the process before described. I now take a piece of sheet brass (square or any other shape), mark the centre with a point; then I tin, as before described, a place about as large as the washer to be used; then I place the tinned side of the washer on the sheet brass, in the centre, which you see through the hole in the washer; let the whole be heated over a spirit lamp, and cooled, and this operation—which will only take a minute or two—fastens the sheet brass to the washer perfectly, and you now can screw the washer on to the chuck. You can thus turn the sheet brass round with perfect accuracy, and mill its edge if you choose, as our silver coin was formerly milled on the edge, and then if you wish to form the bottom or top of a metal box, you can turn a groove to receive the body of the box. To disconnect the finished disk from the washer, you heat it over the lamp, and separate the two while hot, rub off most of the tin with a piece of newspaper, and, when cold, the rest of it with sand paper. I have before me a flat, round brass match box, made in this way; grooves were turned in the top and bottom disks, and short pieces of brass pipe were soldered into the grooves in the same way as above described; the bottom was turned with eccentric circles to strike the match on, and the top ornamented with looped figures by an elliptical cutter; the box was then bronzed, it might have been plated or gilted.

"The above description illustrates only one kind of 'solder chuck' for turners. It will suggest, however, a variety of other plans for attaching work to be turned by the adhesive properties of solder. For instance, when I wish to turn steel 'in the air' with great accuracy, I bore a hole into a brass chuck to receive one end of a bar of steel, which I solder into it, and thus avoid the possibility of shaking, so usual in universal or die chucks."

(81.) *The Displacement Lubricator.*—"Last week, in a paragraph, we called attention to Mr. Ramsbottom's patent, to which attention may again be directed as introductory to the illustrations we have considered it necessary to give in further explanation of the patent.

"The lubricator, as shown in Fig. 28, consists of a spherical vessel, *A*, for containing the oil or lubricator; the vessel is connected by means of a swan-necked branch, *B*, to the cylinder or steam pipe, as the case may be. To put the lubricator in action the plug *C* is unscrewed, and the vessel completely filled. The plug is then replaced. When working, the steam enters the

Fig. 28.

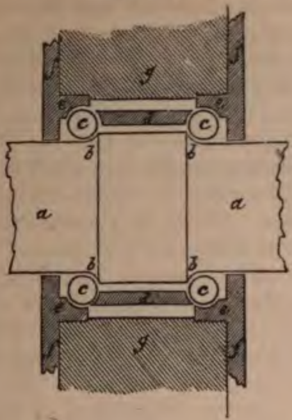


branch, and a portion is condensed on the surface of the oil exposed at the orifice *d*; this portion, being heavier than oil, sinks to the bottom of the vessel, and displaces a corresponding quantity of the lubricant; the vessel is consequently always full, either of the lubricant or the water, or both. The water may be removed by a syphon in the usual way. In the case of a high pressure stationary engine, the vessel is mounted on a bracket attached to the wall of the engine-house, with an inclined pipe connected to the cylinder cover direct. In this case the vessel may be made large enough to contain a week's supply. The arrangement at Fig. 28—*application to the* steam pipe direct—is the preferable one, being applicable to any kind of stationary engine. It may be here added that the plug, *E*, is merely for convenience of manufacture, and should never be taken out. In order to be able to refill the vessel whilst the engine is at work, a screw valve is applied to the break at *B* when required."—*English Mechanic.*

82. *Rolling Friction.*—"For a considerable period," says a writer in the 'Mechanics' Magazine,' "the practical mechanic has endeavoured to find means to avoid the friction of all descriptions of shafting in their bearings; the importance of such a discovery is therefore universally recognised. The inconveniences attending every method at present in practice are well known; it is therefore unnecessary to enumerate them. All that has hitherto been done is to economise in various ways the lubricating agent, as, for instance, by substituting oil for grease, by arrangements more or less ingenious, of which several have succeeded to an extent, and have been used on an extensive scale in large and powerful machinery. Scarcely satisfied with this, and looking deeper into the matter, Messrs. N. Bailly, C. Durand, G. H. Mesnard, and Z. Poirrier, have attained a result which enables them entirely to dispense with lubrication by greasy matter, to give a much more free and easy motion, and sensibly lessen the wear of the parts in contact. This is effected by the substitution of rolling friction for that of rubbing surface in the bearings of shafting in machinery and axletrees in all kinds of vehicles.

"The system for horizontal bearings, of which an engraving is annexed, consists in the application of spheres A, fig. 29, to each end of the bearing, such spheres rolling in throats or necks *a*, *a*, is turned upon the shaft or axle B, and in the end plate C, which spheres are always kept equidistant from each other by a cylindrical envelope D, with embrasures in the ends to receive the spheres, the action of which envelope is to turn the spheres about in every sense, thereby ever changing in the most complete manner the points in contact, and producing, according to the inventors the most harmonious motion yet discovered, reducing friction to a minimum, rendering lubrication unnecessary, while, from the rolling action the bearings can never become hot. It will be seen from the engraving that each bearing is in itself a perfect thrust

Fig. 29.



endering those expensive arrangements at present in use
ssary. It will also be immediately recognised that in the
st of this arrangement it is positively less than the present
er block, with its brasses, &c. . . . .
ree distinct principles of economy result from this inven-
-1st. Dispensing with the use of lubricating matter, while
ing friction will never be sufficient to develope heat enough
er the bearings hot, as has been satisfactorily proved by
ctical experience of the patentees. 2d. A very material
on in the power required to overcome the resistance,
the easy movement of the axles in their bearings, and
ently a considerable saving of fuel. 3d. Very little wear
parts, inasmuch as there is no rubbing surface."

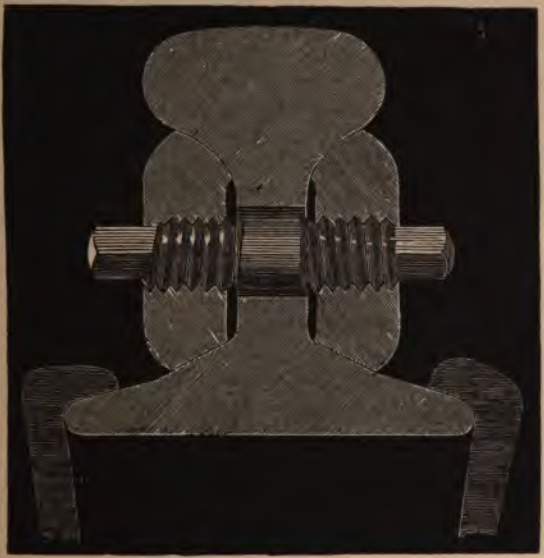
On Locking Nuts and Screws.—From a profusely illus-
article in the "Engineer," June 9th, 1865, we take the
g extracts:—"To nothing more than to practical me-
is the Spanish proverb applicable that 'for want of a nail
e was lost, for want of a shoe the horse was lost, for want
rse the rider was lost, and fell into the hands of the ene-
The mechanic who neglects small things will fall through
hings, and many an accident has been caused by the ne-

glected loss of a split pin. A nut or female thread is only kept on the screw by means of friction, and there is, in most applications of a nut, a continual tendency for it to overcome the friction that keeps it from running down the spiral inclined plane. Jar or vibration, which simply means a more or less amount of shaking, greatly intensifies this action, and sooner or later the unlocked nut must get shaken back in the only direction it can follow. This effect is naturally very much felt at the fish joints of permanent way, by means of the continual jar caused by the passage of the trains. Mr. P. M. Parsons once stated, before the Institution of Civil Engineers, that he had examined, on one occasion, a number of fish-plates which had been laid down about twelve months on the Great Western. He found that 'in 125 pairs of joints, each pair having eight bolts, 261 bolts were loose, and six were out altogether, though they had been tightened up within forty-eight hours.'

"A very great number of devices have been accordingly introduced for locking nuts, more or less efficient, and more or less applicable to a number of different cases. It is clear that good workmanship, producing a proper and equable friction, must be one of the soundest means for keeping a nut tight, and making it less liable to be shaken off. A true fit between the thread and the nut prevents any unequal strain, and, inducing proper adhesion between the surfaces, keeps the parts from shaking loose, and does not allow any range for the jar. The bearing surfaces of the bolt-head of the face of the nut should be square with the axis of the bolt, while the hole in the objects screwed up should be similarly square with their surfaces. A bearing on one side, and on a narrow surface, must both strain the threads and quicken the loosening tendencies of vibration. Absolute practical truth of this kind is, however, only obtainable by very good workmanship, which will always be more or less expensive. . . .

"Amongst the rough and ready plans for the purpose is riveting back the end of the bolt on the nut. This is often done with the bolts used for fastening wheel tires to the rim. For our own part, we cannot see why a rivet should not be used at once—at least in this case. Corrosion also sometimes fastens a nut on as tightly. Very generally used devices are pinching screws, split pins, and split cottars. These are generally calculated for a fixed

Fig. 30.



and unvarying position of the nut, but locking plates (or plates fitted over one or more heads), and more especially lock nuts (or an additional nut above another) allow periodical adjustment to wear or other necessities. Lock-nuts, however, though the most generally used of all contrivances of this kind, are subject to several difficulties. The principle upon which they act is that the pair bring each other into mutual strain and friction against the threads of each.

"The greatest demand for a cheap and efficient means for locking nuts is evidently to be met with on permanent way. This is due, in the first place, to the necessarily cheap and inferior workmanship employed in making the numerous bolts required for the fished joints of a line, and to the continual vibration acting on an innumerable number of bolts spread over long distances. It is thus natural to expect that Mr. W. Bridges Adams, who has given so much attention to permanent way, should have also proposed and introduced a number of contrivances for counteracting the continually-felt evil of the bolts and nuts of the joints getting loose. Amongst these is that consisting of 'a wedge-form washer or collar,' placed between the hole in the fish, and round the bolts, 'so that, when screwed up, it will jam the bolt hard.' The next plan of Mr. Adams is that of a wedge-shaped piece of plate, driven in between the nuts, the under side of the heads of which are bevelled at all the four corners, 'or a groove may be formed round the side, or across them, so as to retain the lock plate; and the lock plates may be curved to act as a spring, or the ends or corners may be made to turn up, to prevent them from getting rent.' As the bolts have to be screwed into convenient positions in order to wedge in the plates, 'washers of more or less thickness may be used to accomplish it.' . . . .

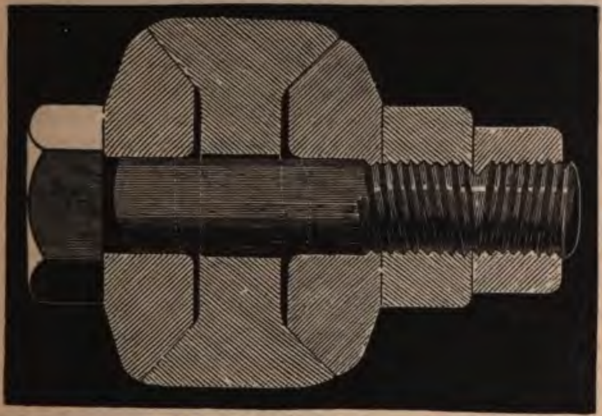
"The counteracting tendency of screws with opposite threads has often been taken advantage of, with more or less success, in keeping themselves from working loose. Amongst these is the plan of Messrs. R. Richardson and J. L. Billups, who fix the fishes of permanent way by means of left and right-handed screws. The fish plates (Fig. 30) are tapped to correspond with the threads of the screws, 'which are turned to draw' the fishes together by means of a key placed on either or both of the heads at their ends.'

"A neat and, probably, effectual device—though not without its disadvantages—is that of Mr. Murphy. He grooves the bolts transversely or even spirally, and into one of these grooves he fits either a pin, or taps a small screw. The number of grooves in the nut and the bolt can be of course varied. By having only one groove in the screw of the bolt and two in the screw of the nut, the key or pin can be inserted at each half revolution of the nut; with one in bolt and three in nut, then the key can be inserted at every third of a revolution, and so on.

"Captain Tyler, one of the inspectors of railways of the Board of Trade, patented some years ago a form of locking plate, to be dropped on the bolts of the fish joints, in order to prevent the nuts getting loose. The woodcut illustrates a plate of this kind, in combination with a form of rail joint afterwards patented by the same inventor. The bolts, as will be observed, have plain *stems*, and heads at each end. One of the heads is of the ordinary shape, the other being oblong. The bolts are made of the length required, and in one of the fishes 'a long and narrow hole is made, corresponding in shape with the oblong head of the bolt.' While the whole is temporarily clipped together, the bolts are inserted and turned one quarter round. A locking plate is then slid over the heads, thus securing them from shaking loose.

"As an improvement on the ordinary jamb nut, Mr. T. H. Falkiner employs two screwed portions of the length of the bolt —the one of larger diameter than the other, and screwed in reverse directions, Fig. 31. On each of these right and left-handed screws is a corresponding nut, the outside one acting as an ordinary lock nut, 'so that it serves the combined purposes of jamming the inner nut and of counteracting the tendency of the bolts to turn loose.' Mr. W. M. Cochrane has re-patented—but only as far as a provisional protection—the plan of Mr. W. B. Adams and other inventors, which consists in placing a thin plate between the nuts and the fishes, the edges of which are afterwards turned up against the sides of the nuts. A similar plate is also turned back against the sides of the bolt heads.

Fig. 31.



"At the annual conversazione, held the week before last at *the Institution of Civil* Engineers, there was exhibited, by Mr.

F. A. Paget, a simple little device for locking nuts, and for also preventing side strain on the threads, which will probably be found generally useful, fig. 32. It consisted in the use of a steel washer, apparently of an ordinary kind, but made of such a shape that on screwing down the nut the compression causes it to act as a spring. A number of different shapes were to be seen, one of which we illustrate. The spring action is, of course, more or less according to the shape and dimensions—proportionately increasing that friction on the threads which would prevent any vibration from turning back the nut. The power of yielding in this kind of washer, would allow it to, so to speak, lap itself or adjust itself, to the surfaces, thus giving greater adhesion than with inferior workmanship. Similarly, its elasticity would take up any inequalities of the surfaces, thereby preventing side strain on the threads; and, in this way also, compensating for want of truth in the bearing surfaces. The use of this spring washer would probably increase the efficiency of the ordinary lock-nut. A lock-nut which is used for details requiring an exact adjustment, such as the brasses of bearings, is subject to a peculiar drawback. When the jamb-nut is screwed down on the ordinary nut, the latter gives way by the amount of its vertical play on the screw. In this way the brasses of a bearing often get screwed down too tightly, and have to be unscrewed and re-adjusted. With a washer affording some spring this action could not take place—or, at least, not so easily. The plan is also clearly peculiarly applicable to small screws, which are always shaking loose. At the present price of steel, washers of this kind, formed with concentric corrugations, could be stamped out at a price little above that of or-

Fig. 32.

dinary wrought iron washers. It is in fact probable that the former prices of steel have stood in the way of the bringing forward of this simple device."

84. *Leather Belts.*—For the following, on this important subject, we are indebted to the "Scientific American :"—"The subject of belts and the peculiar action of them under certain circumstances and the conditions under which they work are of the greatest importance to mechanics and manufacturers. We print in this issue several communications from practical men which refer to some peculiarities not generally known or observed, and we deem it important enough to the arts to devote considerable space for a time to a full elucidation of the subject. We direct research and attention to some other features not yet remarked which may afford useful data to persons using power. We put these questions as follows :—

"Is a thick belt better than a thin one, or the reverse?

"When belts stretch on one side, as they do from a looser texture of the leather, or from other causes, why do they run harder and run off? Why is it that some belts never will run straight on the pulley but twist like a corkscrew?

"Is the hair side or the flesh side to be put next the pulley?

"Is there any thing better than neats foot oil for belting, to keep it in good order. Is a crowned pulley or rounded face necessary to make a belt run true? Some machines which run at high velocities have pulleys with flat faces. Why should a belt be laced straight on the inside and crossed on the outside?"

. . . .

"The horse-power of belting or the tractive force exerted by leather bands of a given width, at a certain speed expressed in foot-pounds, or in any other positive way, is not generally known. We do not know what it is, although we have some half dozen rules professing to give a unit for a horse-power, which are obviously incorrect. A horizontal belt of a given length will drive more than a vertical belt of a given length; a long belt more than a short one, and a twisted belt more than either, because in the case of the horizontal and the long belt, the sag and weight tend to produce closer contact and resist strain better than where the belt merely hugs the pulley by its tension; the same is true of the crossed belt, which embraces more of the circumference of the wheel driven.

"Eight hundred feet per minute velocity for a one-inch belt is said to give a horse-power; four hundred for a two-inch belt will give the same; but these statements appear so crude and unsatisfactory that we place no reliance on them, and we want more facts and less fancy when dealing with such subjects.

"The dynamometer affords an easy, simple, and cheap method of testing strains or the transmission of power from one machine to another, and a few experiments by it would settle forever all doubts and uncertainty on this point. The dynamometer merely weighs strain as a butcher weighs meat, and with the same instrument—a spring balance. If a lever be made with a bearing, cap and bolts at one end, and the same fitted to a shaft, and if a spring balance be applied to the other, by weighting the lever until it balances the tendency to raise imparted to it by the shaft, we shall have an exact record of the actual number of foot-pounds of work or strain exerted by the machine tested, when the relations between the diameter of the shaft and the length of the lever are considered. Of course, with such a dynamometer there is great friction, and if the test is continued long, much heating on the shaft occurs, which would interfere with a correct result; one sufficiently correct for practical purposes may, however, be obtained if the experiment be made properly.

"There are many other forms of dynamometers for weighing or observing the force of machines, but it seems unnecessary to consume space with details of them, when it is apparent to all persons who would be likely to undertake the experiments here recommended, what such apparatus should be.

"Some things relating to the action of belts are but imperfectly understood, for although Morin's experiments have demonstrated the relative resistances of belts on pulleys of different materials and surfaces, such as rough cast-iron, smooth cast-iron, wood, etc., he has not informed us of their position, their nature, whether vertical, horizontal, or twisted, and whether the ratio of resistance increases in regular progression from a belt one inch in width at 400 feet up to a belt 30 inches wide, at the same velocity. It is obvious that these matters exercise a great influence on the transmission of power by belting.

"From an experiment at one of our largest machine shops, it was found that gearing absorbs less power than belts, and that the force required to work the latter is extremely variable, depending upon the tension, the condition of the surface of the pulley, and minor matters. This fact was deduced from observing the working of a fan blower, and is to be received with caution, for it has hitherto been supposed that gears consumed more power than bands, and these results may be due merely to the peculiar arrangement of this special machine. It is a fact, however, that the use of sawdust, resin, or similar substances, to increase the adhesion of the belts to pulleys, as also the employment of idler pulleys, or rollers suspended against belts to keep them up to their work, also the divergence of belts from right lines or carrying them at acute angles about rollers fixed in walls, add greatly to the expense of working them.

"Since belts are so universally employed, a series of experiments on this subject would be invaluable, and we hope that those who have the time and the means, as well as others who possess experience derived from actual practice, will send us what information they may possess on this subject."

. . . .

"The difficulty alluded to in our article of estimating exactly what power is transmitted by a belt is not solved by our correspondent's communication, although he gives so much that is interesting, and is a thinking man. He assumes that the belt (rule 1st,) gives or transmits 22½ H P, but is this an inference or the result of actual experiment, or practice, which is better? A belt transmitting 22½ H P will have to raise 742,500 lbs. at the rate of one foot high in a minute, and that the force exerted is materially changed by the conditions the belt works under is very certain from the data furnished by Mr. Cooper.

"A 12-inch belt running on a 5½-foot pulley at 45 revolutions per minute would be very slack not to transmit more than 12-horse power. We know of an 11-inch belt that daily transmits, from a 4-foot pulley running 60 per minute, the power exerted by an 11-inch cylinder and 30-inch stroke running 45 revolutions per minute with 50 pounds of steam. In this comparison the advantage is with the 5½-foot pulley, for the speed *of the belt over it, in* lineal feet, is 780, while the smaller pulley runs 753 feet per minute. The power thus carried off by this belt (vertical) without an idler pulley is, by the rule for estimating the powers of steam engines, 29-horse power.

"Let it be understood that we do not criticise our correspondent's letter in a spirit of fault-finding, but with a view to further information in the case.

"On page 84, Vol. III., of the 'Scientific American,' we published some interesting rules and facts relating to the transmission of power by belts, and the opinion is there expressed that but little reliance can be placed on rules in general, for so much depends on the elasticity, length of belt, and velocity of the same, that arbitrary formulæ do not always suit the case. We are not of this opinion now, and see no reason why, when the length and width of the belt is given, we should not have an approximately correct result, with the ordinary tension, that is a stretching that will neither tear out the lacing, or the holes, or heat the shaft, but be sufficient to cause a moderate and proper adhesion. Of course, in this case, common sense must be used to determine what reasonable tension means.

"As our correspondent remarks, the experiments with the india-rubber and the leather belts proved nothing. Mere adhesion of two surfaces, or one slipping under a less load than the other, with the same width, is no criterion, for by applying foreign substances, such as rosin, or oil and rosin, the adhesion can be greatly increased, and a small belt made for the time to draw as much as one of greater sectional area."

85. *Purification of Lubricating Oil.*—"Oil for lubricating purposes is very high at the present time, and should be carefully used. Much of it is not only lost by improper use, but is actually thrown away by persons who are too reckless or naturally too wasteful and regardless of their own property to take any care of that belonging to others. It is a little singular that men who are thought unfit for higher positions are generally made to oil the shafting in factories, where they can waste a gallon every day by slovenly and stupid use of it.

"When oil is poured on a bearing, if the shaft be in motion, it takes up a supply enough to cover the surface, while the superfluity runs off at the nearest outlet. If there happens to be a *drip pan* underneath the hanger, the oil is caught, and when the pan gets full, the contents are summarily thrown out of doors into the nearest waste hole.

"Although much of this oil is full of metallic dust, the result of wear, that does not prevent it from being used again when properly treated to remove the foreign matters. This can be done so simply and so easily, that we think much economy to manufacturers will result from the adoption of the following process:—

"When the oil is taken from the drip pan, it should be poured off carefully, so that the heaviest part of it, which settles at the bottom, may be treated separately. The lightest or upper portion should be put in a vessel and heated gradually to a little below the boiling point of water. From this vessel it should run through flannel, to filter it, which will remove the finest metallic dust held in suspension by the oil. From this filter the oil will come out semi-transparent, but in a great measure free from the grosser impurities. A filter of *animal* charcoal, or coal made by burning bones, should then be used, which will detain the dirt that still remains behind, and render the oil fit for use again for most purposes.

"Oil thus treated will not have the bright and clear appearance of that bought in barrels, but it will be very good, and may be used over and over again with comparatively small waste. Animal charcoal can be had of all wholesale druggists.

"For large works, it would be profitable to have a place prepared particularly for the object of purifying the waste oil by the means above described. Other and more complicated processes are employed by refiners to extract impurities from oils, but they are obviously unsuited to persons not acquainted with chemical changes and affinities, and would be useless to our readers. We do not see why it would not be a profitable scheme for those versed in such matters, to collect the waste oil from drip pans and render it pure again for a small sum per gallon. It is not only the spent oil which falls into these drip pans, but that lavishly poured over the hanger by the oiler, so that the contents are very different from common slush. The process above described has been tried on a large scale, and is not a mere experiment."

DIVISION SEVENTH.

METALS AND METAL MANUFACTURES.

86. *The "Bessemer" Processes of Steel-Making.*—Those interested in the use of iron and steel in construction are well aware of the important innovations in their manufacture introduced by Mr. Henry Bessemer, so important that they may be said to be fast bringing about, if indeed they have not already brought about, a complete revolution in the iron and steel trade. Everything, therefore, bearing practically upon the processes of Mr. Bessemer is sure to be interesting and useful. The following is an abstract of a paper read by the inventor before the late meeting, at Birmingham, of the British Association, in which much will be found that is suggestive. The paper is entitled,

On the Manufacture of Cast-Steel, its Progress, and Employment as a Substitute for Wrought-Iron.—"On the 13th of August, 1856, the author had the honour of reading a paper before the Mechanical Section of the British Association at Cheltenham. This paper, entitled 'The manufacture of Malleable Iron and Steel without Fuel,' was the first account that appeared shadowing forth the important manufacture now generally known as the Bessemer process. . . . .

"In the original fixed converting vessel, as patented and erected in London for experimental purposes in 1856, the tuyeres were passed through the sides of the vessel in a horizontal direction, the result was that the blast of air entered only a short distance into the fluid mass, and much of it escaped upwards between the sides of the vessel and the metal. The effect of this was the rapid destruction of the brick lining, caused by the excessive temperature generated in the process, and the solvent property of the resulting silicate of protoxide of iron, which sometimes destroyed a lining of half a brick in thickness during the blowing of two charges of metal for about twenty minutes each. Another difficulty arose from the impossibility of stopping the process without running out the metal, for if the blowing ceased for one instant the fluid metal would run into the tuyeres, and stop them up.

"A great inconvenience of the fixed vessel also arose from the danger and difficulty in tapping out the fluid malleable-iron with a bar, after the manner of tapping an ordinary cupola furnace, for the blast had to be continued during the whole time the charge was running out of the vessel, in order to prevent the remaining portions from entering the tuyeres. A similar difficulty arose while running in the crude metal from the melting furnace, since it was necessary to turn on the blast before any metal was run into the vessel, the first portions so run in were, in consequence, partially decarbonised before the whole of the crude metal had left the melting furnace. These were among the more prominent difficulties that had to be remedied. . . . .

"It may be remembered that an important part of the process, as described at Cheltenham in 1856, consisted in tapping the fluid crude iron from the blast furnace, and allowing it to flow direct into the converting vessel, and be there blown to the extent only of decarbonising it so far as to produce cast-steel. This part of the original programme has been most successfully carried out in Sweden, where an extensive establishment for its manufacture has been erected by M. Göranson, of Geffle. . . . .

"After giving a few illustrations of the capabilities of the process as originally described at Cheltenham, the author proceeded to show how the disadvantages of the old fixed converting vessel were remedied and other improvements introduced. Many forms of converting vessels were tried on the large scale before this desirable object was attained. In some of them the lining was too easily broken down by the violent motion of so heavy a fluid as iron; in some of the forms tried the angles allowed the metal to solidify in them, and so clog up the vessel; in others, the mouth of the vessel being too small, caused the metal to be thrown out by the force of the escaping blast. It was also found that if the mouth was too large the heat escaped, so as to cause part of the converted metal to solidify in the vessel; the relative height and diameter of the vessel was also found to produce important differences in the working of the process; finally, and after many long and expensive trials, a peculiar form of vessel was adopted. This vessel is made in two parts, so as to admit easily of its being lined up with a pulverised silicious stone, known as 'ganister,' which so resists the action of the heat and slags as to last for fully 100 consecutive charges of steel before it is worn out. Its form is that of the arch in every position, which prevents the lining from falling down by its own weight. There are no angles in which the splashes of metal can solidify and accumulate. Its mouth directs the flame and sparks away from the workman, and from the moulds and other apparatus; while the throat of the vessel, and the position of the mouth, almost entirely prevents the throwing out of the metal. The vessel is mounted on trunions supported on stout pedestals, so that a semi-rotary motion may be communicated to it at pleasure. The tuyeres are placed at the bottom of the vessel, so as to force the air vertically upward through the metal without coming in contact with the sides of the vessel. When the crude metal is to be run into the vessel it is turned on its axis; a gutter will then conduct the crude cast iron from the melting furnace into it. It is not necessary to turn on the blast until the whole of the metal is run in, because the tuyeres occupy a position above the level of it. As soon as the air is admitted through the tuyere the vessel is turned into another position when its decarbonisation immediately commences. As soon as this is effected, as much molten pig iron made from spathose iron ore is added to it as will restore the quantity of carbon necessary to produce the desired quality of steel, which is then run into the casting ladle, and from whence it is transferred to a series of iron moulds ranged in a semicircular pit, each mould being placed within the sweep of the casting crane; the filling of these moulds is regulated by a cone valve made of fire-clay, and fitted in the bottom of the casting ladle, so as to be opened or shut at pleasure by means of a handle on the outside of the ladle. . . . .

"Up to this period the manufacture of cast-steel by the old as well as the new process is still so far imperfect that steel of the highest quality cannot be made from inferior iron. In the old Sheffield process the original quality of the Swedish charcoal iron employed governs the quality of the cast-steel made; consequently, £36 per ton is freely given for the high class Danamora iron, while other brands of Swedish charcoal iron may be bought for £15. In either case these are expensive raw materials for the cast-steel maker.

"In 1839 the trade of Sheffield received an enormous impulse from the invention of Josiah Marshall Heath, who patented in this country the employment of metallic manganese, or, as he called it, carburet of manganese. The addition of a small quantity of this metal, say from one-half to one per cent., rendered the inferior coke-made irons of this country available for making cast steel; it removed from these inferior qualities of iron their red-shortness, and conferred on the cast-steel so made the property of welding and working soundly under the hammer. This invention was of immense importance to the town of Sheffield, where its value was at once appreciated. Mr. Heath, supposing himself secure in his patent, told his licensees, that if they put oxide of manganese and coal tar or other carbonaceous matter into their crucibles along with the blister steel, that it would do as well, and be much cheaper than the carburet of manganese he was selling them; in effect it was the same thing, for before the steel was melted the carbon present reduced the oxide of manganese to the metallic state, so that his patent carburet of manganese was formed in the crucible in readiness to unite with the steel as soon as it became perfectly fused. But the law decided that this was not Heath's patent, and so the good people of Sheffield, after many years of litigation, were allowed to use it without remuneration to the inventor.

"Manganese has now been used for many years in every cast-steel works in Europe. It matters not how cast-steel is made, since manganese added to it necessarily produces the same beneficial changes; no one better appreciated this fact than the unfortunate Mr. Heath, as evidenced by his patent of 1839, in which he declares that his invention consists in 'the use of carburet of manganese in any process whereby iron is converted into cast-steel.' Had Heath seen in his own day the Bessemer process in operation, he could not have said more; he well knew the effect produced by manganese on steel, and, therefore, claimed its employment in any process whereby iron is converted into cast-steel.

"With this patent of Heath's expired, and become public property, coupled with the universal addition of manganese and carbon to cast-steel, it would naturally be supposed that the author, in common with the rest of mankind, would have been allowed to share the benefits which Heath's invention had conferred on the whole community, but it was not so."

After showing how a number of patents were taken out, in opposition, and how some gentlemen even repatented portions of the writer's own patents, while others patented things in daily use, in the hope that they might be considered new when added to the products of the new process, the author proceeds :—

"Within six weeks of the date of the Cheltenham paper, Mr. Robert Mushet had taken out three patents, which form part of that long series of patents by which he hoped to secure to himself the sole right to employ manganese in combination with iron or steel made from pig iron by forcing atmospheric air through it. In this long series of patents almost every conceivable mode of introducing manganese into the metal is sought to be secured. . . . . . . In fact, manganese and its compounds were so claimed under all imaginable conditions, that if this series of patents could have been sustained in law it would have been utterly impossible for the author to have employed manganese with steel made by his process, although it was considered by the trade to be impossible to make steel from a coke-made iron without it. . . . .

"Very soon after the reading of the Cheltenham papers, several rough trials of the Bessemer process were made privately by persons in the iron trade, and defects discovered which were supposed by practical men to be perfectly fatal to the invention. Once more the press teemed with accounts of the process, but this time it spoke only of its utter impracticability, and of regrets that the expectations originally formed were so fallacious. The storm, however, gradually subsided, and the process and its author were soon entirely forgotten. Imperfections in the process there certainly were, but the author had had the most irrefragable proofs of the correctness of the theory on which his invention was based, and also that the reasoning on which it was so utterly condemned by the trade was in itself wholly fallacious ; he therefore decided not to argue the question against a hundred pens, but to energetically prosecute his experiments, and to remain silent until he could bring the process to a commercial success. When, at the expiration of about three years of incessant labour on the part of himself and partner, Mr. Longsdon, and an expenditure of more than £10,000, the process was again brought before the public, not the slightest interest was manifested by the trade ; it had been for years agreed on all sides that it was a total failure, and was looked upon simply as a brilliant meteor that had suddenly flitted across the scientific horizon, leaving the subject in more palpable darkness than before. This entire want of confidence on the part of the trade was most discouraging; one of two things became imperative, either the invention must be abandoned, or the writer must become a steel manufacturer; the latter alternative was unhesitatingly accepted, and Messrs. Henry Bessemer and Co. determined to erect a steel works at Sheffield, in the very heart of that stronghold of steel making. At these works the process has ever since been successfully carried on; it has become a school where dozens of practical steel makers received their first lessons in the new art, and is the germ from which the process has spread into every state in Europe, as well as to India and America.

"By the time the new works at Sheffield had got into practical operation the invention had sunk so low in public estimation that it was not thought worth paying the £50 stamp, due at the expiration of three years, on Mr. Mushet's large batch of manganese patents; they were, consequently allowed to lapse and become public property.

"The author, has, therefore, used without scruple any of these numerous patents for manganese, without feeling an overwhelming sense of obligation to the patentee.

"At the suggestion of the author a works for the production of manganese alloys was erected by Mr. Henderson, at Glasgow, who now makes a very pure alloy of iron and manganese, containing from twenty-five to thirty per cent. of the latter metal, and possessing many advantages over spiegeleisen, which it will doubtless replace. Two bright rods of 1⅞ in. diameter will be found on the table, they were folded up cold under the hammer. This extremely tough metal is made by using Mr. Henderson's alloy in lieu of spiegeleisen, which is incapable of making steel of such a quality.

"A Prussian gentleman, M. Preiger, has been also successful in manufacturing a new alloy, which he calls ferro-manganese, consisting of sixty to eighty per cent. of metallic manganese. It is extremely useful in making malleable iron by the Bessemer process, in which spiegeleisen cannot be employed on account of the large proportion of carbon it contains.

"It is gratifying to turn from a review of the troubles and impediments of the past, and briefly notice some of the more important applications of steel as a substitute for wrought-iron.

"In no case is this change of material more important than in the construction of ships, for in no instance are strength and lightness more essential.

"The Bessemer cast steel made for ships' plates by the several eminent firms now engaged in that manufacture, is of an extremely tough and ductile quality, while it possesses a degree of strength about double that of the inferior kind of iron plates usually employed in shipbuilding, hence it is found that a much less weight of material may be employed, and at the same time a greater degree of strength may be given to all parts subjected to heavy strains. . . . .

"The application of steel for projectiles has now become a necessity since the introduction of armour plates. We have before us a 110 lb. shot, that has passed with very slight injury through a 5-inch armour plate, and also some specimens of bent angle iron, made of Bessemer iron, and rolled at the Millwall Ironworks, in London, and from the same works a portion of one of Hughes' patent hollow steel beams for supporting the armour plating in course of construction for the forts at Cronstadt; both these are interesting examples of what the rolling mills of the present day can effect, and of the facility with which cast malleable iron and cast steel admit of being worked into the most difficult forms.

"There is no department in engineering in which the peculiar toughness of steel, and its strength and power of resisting wear and abrasion, are of such vital importance as in its application to railway purposes. This fact had long since impressed itself strongly on the mind of Mr. Ramsbottom, of the London and North-Western Railway, who commenced experiments with this material in 1861; carefully, though trustingly, he tried it step by step, not even at first venturing to employ it for passenger trains, but as proofs of its safety and economy crowded upon him, he carefully applied it to the most important parts of passenger *engines*, and even to the manufacture of the formidable engine cranks (at that time entrusted only to the most eminent iron-making firms in the kingdom) these iron cranks are now being replaced by steel ones forged from a single mass. One of these steel cranks, manufactured at the new steel works at Crewe, has been obligingly lent by Mr. Ramsbottom as an illustration of the use of steel for this purpose, that gentleman has also taken out of use a plain steel axle that has run a distance of 112,516 miles, and now exhibits very slight signs of wear. . . . .

"So important were found to be the advantages of employing cast steel as a substitute for wrought-work at the works of the London and North-Western Railway Company, that the directors, acting under the advice of their able engineer, determined on building a large steel works at Crewe, which is now in active and successful operation. In the design and arrangement of their plant for working up the steel several important improvements have been introduced by Mr. Ramsbottom, among others his duplex hammer, which strikes a bloom on both sides of the ingot at once, in a horizontal direction, and thus renders unnecessary the enormous foundations required for ordinary hammers. Here also, he has put up his improved rolling mill for rolling blooms of large size, the enormous machine being reversed with the greatest rapidity and ease by the attendant, without any shock or concussion whatever.

"While matters were thus steadily progressing in the engine department of the company, the engineer of the permanent way, Mr. Woodhouse, took in hand a thorough investigation of a no less important problem—viz., the substitution of cast steel for wrought-iron railway bars. For this purpose some 500 tons of rails were made, and put down at various stations where the traffic was considerable, so as to arrive, at the earliest period, at a true comparison of the respective endurance of wrought-iron and cast-steel rails. It will be unnecessary here to enter into the numerous details of the extensive series of experiments systematically carried out by Mr. Woodhouse; the trials made at Camden will suffice to show the extraordinary endurance of steel rails. It is supposed that there is not one spot on any railway in Europe where the amount of traffic equals that at the Chalk-farm bridge at Camden-town. At this spot there is a narrow *throat in the line, from* which converges the whole system of rails employed at the London termini of this great railway. Here all passenger, goods, and coal traffic have to pass; here, also, the making up of trains and shunting of carriages is continually going on. At this particular spot two steel rails were fixed on May 2d, 1862, on one side of the line, and two new iron rails were on the same day placed precisely opposite to them, so that no engine or carriage could pass over the iron rails without passing over the steel ones also. When the iron rails became too much worn to be any longer safe for the passage of trains, they were turned the other way upwards, and when the second side of the rails were worn as far as the safety of the traffic would allow, the worn out rail was replaced by a new iron one—the same process being repeated as often as was found necessary. Thus we find, at the date of the last report, on March 1st, 1865. that seven rails had been entirely worn out on both faces. Since then another has been worn out up to July, making sixteen faces worn out, the seventeenth face being in use on August 22d, when the steel rail that had been placed opposite to them was taken up in the presence of the writer, and, by the kind permission of Mr. Woodhouse, now lies on the table before the meeting. Taking its resisting powers at three more faces only, it will show an endurance of twenty to one in favour of steel. . . . .

"In conclusion, it may be remarked that cast-steel is now being used as a substitute for iron to a great and rapidly increasing extent.

"The jury reports of the International Exhibition of 1851 show that the entire production of steel of all kinds in Sheffield was, at that period, 35,000 tons annually, of which about 18,000 tons were cast-steel, equal to 346 tons per week; the few other small cast-steel works in the country would probably bring up this quantity to 400 tons per week as the entire production of cast-steel in Great Britain. The jury report also states that an ingot of steel, called the 'monster ingot,' weighing 24 cwt., was exhibited by Messrs. Turton, and was supposed to be the largest mass of steel ever manufactured in England. Since that data a great change has been made, for the largest Bessemer apparatus at present erected in Sheffield, at the works of Messrs. John Brown and Co., is capable of producing with ease every four hours a mass of cast-steel weighing 14 tons, being twenty times larger than the 'monster ingot' of 1851.

"There are now seventeen extensive Bessemer steel works in Great Britain. At the works of the Barrow Steel Company 1,200 tons per week of finished steel can easily be turned out, and when their new converting house, containing twelve more five-ton converters, is completed, these magnificent works will be capable of producing weekly from 2,000 to 2,400 tons of cast-steel. There are at present erected and in course of erection in England no less than sixty converting vessels, each capable of producing from three to ten tons at a single charge. When in regular operation these vessels are capable of producing fully 6,000 tons of steel weekly, or equal to fifteen times the entire production of cast-steel in Great Britain before the introduction of the Bessemer process. The average selling price of this steel is at least £20 per ton below the average price at which cast-steel was sold at the period mentioned. With the present means of production therefore, a saving of no less than £6,240,000 per annum may be effected in Great Britain alone, even in this infant state of the Bessemer steel manufacture."

87. *The Bessemer Metal.*—"At a time," says a writer in the "Engineer," "when there is so much doubt as to the issue of the great trial of capital *v.* labour, in the iron trade, it will be interesting to know how far science is superseding those processes in which labour is so largely required. The puddlers, just now, form the larger proportion, perhaps, of those locked out on strike in the iron districts; or if not actually the most numerous, they are those whose labour it is least convenient to dispense with. It may be that we can never do without puddled iron, and we may be sure that as long as iron is known as iron, we cannot do without iron-workers of some class or other. First, we have had much reason to hope for the success of machine puddling, but this success is by no means yet established. Puddling is a process nearly a century old, by which melted crude iron is mechanically stirred up to the air in order that its carbon and silicon may be burnt out by oxygen. It may seem as simple a matter to make a 'stir-about' in an iron furnace as in a kettle of Scotch oatmeal and water, but somehow we have found it necessary to employ a skilled *salamander for* the former operation. A good many have

tried mechanical stirring, or 'puddling,' for the iron, as worked by hand, is melted and stirred in a puddle, say, 2 ft. in diameter, and only a few inches deep. Some years ago Captain Bernard Walker undertook to churn the melted crude iron in a rotary churn, and we believe good blooms were made. Later, Mr. Tooth took up the idea in a modified form, and he set up a pair of steam puddlers, or rotary puddling machines, in the yard of a house in the Rhodeswell-road, Stepney. Of these we had something to say four years ago. Good blooms were made, but not, perhaps, with certainty. Some of the South Staffordshire masters found these blooms to consist partly of unrefined cast iron. But the idea survives, and it is in course of further trial at Dowlais, where, if anywhere, it should be best turned to practical account.

"But the great rival of the puddler, in the case of a large amount of iron, is the Bessemer 'converter.' Instead of working the iron about to expose it to oxygen (and this is the purpose of puddling), the oxygen is pumped through the melted iron, the difference in the weights thus handled being about as four thousand to one. It is between eight and nine years since the Bessemer process was first known. It then appeared too good to be true, and yet it was worked with success. Mr. Bessemer found difficulties, however, in dealing with the larger proportion of British iron, and difficulties also in the working of his earlier apparatus. But he persevered, and was rewarded by the knowledge that he could obtain metal of great hardness and toughness from certain abundant varieties of iron, and that the manufacture could be brought far within a limit of cost to which no other process, with a like object, had ever approached. Many thousands of tons of 'Bessemer metal'—for the 'trade' are not quite sure whether it is iron or steel, although it is really both in one—are now made yearly, and there need be little prediction in stating that, in the ordinary course of successful progress, many hundreds of thousands of tons will yet be made annually. . . . .

"We believe some small plate girders of Bessemer steel have been constructed, but its advantages would appear chiefly in large spans, where, in the case of iron, the weight of the bridge itself forms the greater part of its own load. For ordinary spans the present price of Bessemer steel leaves no margin of advantage to the engineer. It is known, however, that it is being learned how to turn the commoner kinds of English iron to good account in the Bessemer process, and as the waste in manufacture is very little, and as a great number of firms are now competing in the business, it is in all respects probable that Bessemer metal will fall rapidly in price, and that its use will be as rapidly extended."

88. *Steel Manufacture.*—From an article in the "Mechanics' Magazine," date July 21, 1865, we take the following description of modes of working steel other than by the Bessemer process:—"A cast steel, very useful for some purposes, is produced from wrought iron by fusion with carbon in a crucible. The degree of hardness attained in the steel depends upon the quantity of charcoal used; for tool steel 1·5 to 1·7 per cent. is introduced; for soft steel less than 1 per cent. is sufficient. This produces a soft metal capable of receiving a high polish, and which casehardens without bending. Some of this steel, or partially carburised iron, has been carefully tested and found capable of sustaining a strain of thirty-five tons to the inch. Under the name of homogeneous iron, a Sheffield firm has also introduced a mild steel of this kind, which takes an average tensile strain of forty-one and a half tons, or double that of wrought iron. A peculiar process of manufacturing steel is adopted at the works of M. Bugeney, near Paris. These works are managed by M. Chenot and his son, from whom Mr. Fairbairn obtained the particulars of manufacture. M. Chenot employs a peculiarly constructed furnace, fifty feet high and about eighteen feet square at the widest part, in which he makes steel direct from the ore by converting it into what he calls sponge. To the main furnace are attached other furnaces containing the fires, the greatest care being taken that the gaseous products alone shall come in contact with the ores. The heated currents from the minor furnaces are distributed through the main furnace by means of numerous intersecting flues, which also serve to equalise the temperature at those parts where they come in contact with the ores. The time required for producing the sponge from the ore is five days. About a ton of this sponge is withdrawn from the furnace every twenty-four hours, by means of a movable grated platform, which is elevated by rack and pinions to the proper height in the

furnace, where it receives the charge, and is lowered at the required temperature to the space prepared for its reception below. The air is carefully excluded by placing a luting of clay all round the platform over which the sponge is removed. Upon the process of calcination, or conversion of the ore into sponge, being completed, it is supplied with carbon by being soaked in oil or other grease. It is afterwards placed in wrought-iron retorts, and exposed to the heat of a furnace for two hours, in order that any excess of carbon it may have received shall be driven off. The next step is to reduce the sponge to a powder, which is afterwards compressed into bars in strong iron tubes by machinery. When it has reached this condition it is fit for melting, and is placed in a crucible with four tons of coke to one of steel. From the crucible it is run into ingots, and is finally prepared for the market by the hammer in the usual way. From this peculiar method of manufacture a superior description of steel is obtained.

"In some works on the continent the German refining process is adopted, and steel is produced from crude iron by the decarburising effect of a blast in a furnace similar to a refinery. The pigs are melted by charcoal, and a strong blast is conducted over the molten surface of the iron. The mass of iron is stirred up so that every portion is brought under the action of the blast. The consolidation of the mass, and the colour of the flame, are the indications by which it is known that the process has been carried sufficiently far. The direct production of steel from cast-iron in the puddling-furnace has for years been a fact well known to manufacturers, but only recently has puddled steel become an article of commercial importance. The process of converting cast-iron into steel by puddling is similar to that employed for puddling iron, with, however, this difference : the iron is subjected to the oxidising action of the flame until the whole of the carbon is extracted, whilst in puddled steel the action is stopped before that point is reached. The iron is usually allowed to retain from half to one per cent. of carbon, and when this degree of carburisation has been arrived at, the puddler closes the damper and collects the steel into balls, which are hammered and rolled in the ordinary way. There is, however, one objection to puddled steel, and that is the want of uniformity to which it is liable. But mistakes in the manufacture may be corrected by breaking the bars, obtained as above, and rejecting the bad ones, the rest being piled, heated, and rolled into plates or bars. With care in selecting the iron, and in making, a tough malleable steel is produced, which has superseded wrought-iron to a considerable extent in boilermaking and shipbuilding. Its tenacity ranges from 35 to 40 tons per square inch, and its cost is about 25 per cent. in excess of that of wrought iron. Captain Uchatius produces cast steel direct from the crude iron by melting the pigs in a cupola, and running the products into a cistern of cold water. In the cistern is a dash-wheel which revolves very rapidly, and by striking the iron causes it to become granulated. The particles are afterwards intimately mixed with oxide of iron in a state of powder, or with sparry iron and fine clay. The quantity of oxidising material used is from 20 to 30 per cent., according to the amount of oxygen required. The ingredients are placed in a crucible, and fused in the steel melting furnace. The oxides cause the granules of cast iron to part with some of their carbon, and a slag is formed which purifies the steel. The quantity of steel obtained is somewhat in excess of the iron introduced, in consequence of a portion of the oxides becoming reduced. The size of the granules affects the quality of the steel; if they are large the steel is hard, if small then the product is a soft steel, owing to the fact that decarburisation proceeds very slowly inwards from the surface. The tensile strength of this steel is about 90,000 lbs. per square inch.

"Allied to the material under notice, is the gun metal produced by Mr. Mushet. It is made by cutting up bar iron into small pieces, each weighing about an ounce, and melting them in steel melting pots. A small proportion of two other metals is added, and from this the peculiar properties of the gun metal are derived. The introduction of charcoal regulates the hardness of the alloy, which, after fusion, is moulded in ingots. The proper treatment for this metal is to roll or draw it out at cast-steel heat, as its tenacity becomes impaired by raising it to a welding temperature. Some samples of this gun metal, tested by Mr. Fairbairn, gave a breaking weight of 46·176 tons per square inch. This, however, does not equal some results obtained from the Bessemer steel by Colonel Wilmot, which gave upwards of sixty-eight tons per *square inch. At the* last meeting of the Academy of Sciences, a communication was received from M. Aristide Bérard upon a new direct method of producing cast steel by means of gases. M. Bérard operates on the melted metal alternately with reducing and oxidising agents. The necessary heat is produced by gases, the furnace used being of the reverberatory class, with two soles separated by a bridge, on which coke is placed to remove the free oxygen. For fifteen minutes air is sent through the metal on one side, the other being treated with a mixture of hydrogen and carbonic oxide free from sulphur. The treatment is then reversed for another fifteen minutes. The process is thus explained. While oxidation goes on, part of the iron is oxidised to protoxide; the earthy metals, such as silicium, aluminium, calcium, &c., are also oxidised, and probably combine with the oxide of iron and form compound silicates. The sulphur, phosphorus, and arsenic also oxidise and pass away. During the process of reduction, the oxide of iron is reduced and the other metals remain in combination with the silica forming scoria, which floats on the surface. Any sulphur, phosphorus, or arsenic which escaped oxidation will then form a volatile hydrogen compound. The final process is that of decarburation, which is effected by the air blast. It is stated that cast steel of very high quality is obtained by this method of treatment. M. Bérard observes that manganese plays an indefinite part, the certain effect of which is to facilitate the process of converting the iron into steel.

"Much has been said and written upon the composition of steel, and various theories have been propounded as to its composition and the elements requisite for the production of the best varieties of steel. M. Frémy has made very extensive experiments, which have led him to form the opinion that iron in its three states—cast-iron, steel, and wrought-iron—is due not only to the different proportions of carbon they contain, but also to the presence of nitrogen. Mr. Mushet, again, has advanced a theory that titanium is essential in the manufacture of steel. Titanium has a great affinity for nitrogen and carbon; and if nitrogen is requisite, it is possible that titanium might act as a carrier of nitrogen and carbon. Upon the whole the investigations and experiments with respect to steel are as yet very limited; knowledge in this direction requires extending, and this is the more important as the use of steel increases. With the development of the manufacture will come a better practical knowledge of its requirements, and out of this only can we hope to establish perfection."

89. *On certain methods of treating Cast-Iron in the Foundry.* (By Zerah Colburn).—After describing the "plant" of the foundry, the "cupolas," and the "blast apparatus," and pointing out what he conceives to be improvements in them, Mr. Colburn proceeds to show,—"1. The means for increasing the strength and hardness of castings. 2. Means for insuring uniform cooling in castings after pouring. 3. The treatment for malleable castings. 4. Chilling.

"At one time when cast-iron was employed for boilers, shafting, large ordnance, and bridges, its strength was of great consequence. It has now become usual to employ wrought-iron or steel for the application just named, and, indeed, wherever great absolute strength is required. Even engine beams, since the lamentable failure at Hartley, are being made of wrought-iron. So the importance of great strength in castings has, no doubt, been lessened, and for most purposes it has been found cheaper to employ a somewhat larger quantity of ordinary iron than to pay a higher price and incur the delay often attending the search for a superior quality. . . . .

"I shall say nothing of the selection of particular brands of iron, nor of the great importance of proper mixing in the cupola, for I could only say, what every qualified founder well knows, that upon these a great deal depends. I could give no directions better than those upon which founders now act, each having to choose and mix the irons which he has found best for his own purposes in his own district, for it is always important to him not to send further than is necessary for his pigs. But there are modes of increasing the strength of a large number, if not all, of the irons known to commerce; and although there is still much doubt as to the relations between the chemical constitution and the strength of iron, it is certain that all the known modes of strengthening cast-iron are modes whereby its proportion of uncombined carbon and of silicium is known to be diminished. If we puddle cast-iron up to a certain extent, and stop at the right point, we have steel of very great strength, and if we carry the puddling far enough we have wrought-iron. So if we melt cast-iron with wrought-iron, as in making what is called Stirling's toughened metal, we lessen the relative proportions of the impurities to the iron as contained in the pig, and if we do not get a remarkably tough metal, we, at any rate, produce one of great hardness, and some of our locomotive makers employ such a mixture purposely to obtain hardness in their steam cylinders. So also, by oxidizing cast-iron at a high heat, as in the treatment for malleable iron castings, we gain undoubted strength and toughness. . . . .

"Now, as all the processes whereby cast-iron is strengthened are processes whereby its proportion of contained carbon and silicium is diminished, some quicker and much cheaper mode of effecting this object is required than that by re-melting or by partial puddling. This quicker and cheaper mode would be had by a partial application of Mr. Bessemer's treatment, that is by blowing air through the iron for perhaps three or four or five minutes, instead of twenty. But, it will be asked, if you are to have the Bessemer apparatus at all, why not convert the iron at once into steel? There are several reasons why we should not. To make steel, a much higher quality of iron, and generally the addition of spiegeleisen, is necessary. As steel the metal cannot be run into goods, but only into an ingot, which requires very heavy hammers to forge it, as well as machine tools of unusual strength to finish it after forging; the wear of the converter and other plant would be much greater for steel than for toughened iron. The waste of metal before the finished article, whatever it might be, could be produced, would be greater for steel than cast-iron. I have recommended this partial application of the Bessemer process, and I believe that when more attention comes to be given to strength in castings, this treatment will be adopted. The apparatus for carrying it out would be exceedingly simple, and would be worked with but little trouble, a blast being derived from the rotary blower already described.

"But absolute strength in the iron of large castings is of little consequence unless they cool, after pouring, in such a manner as not to leave them subject to considerable internal strains. We know that the late Professor Hodgkinson found that with the iron he experimented upon the compressive strength was six *times that* in tension, and hence that the bottom flange of a cast-iron girder should have six times the sectional area of the top flange. But very few, if any, engineers adopt such a proportion, as the casting would in all probability crack in cooling. . . . .

"To make a casting of great strength it is necessary that all parts cool alike or nearly so. In the case of guns cast solid, the core bored out is often found honeycombed by retarded cooling; and the metal forming the surface of the bore can be proved to be under considerable initial strain in consequence. Of course guns were cast hollow many years ago; but not until 1847 was it proposed to cool the core, after casting, by means of water circulating in pipes within it. Captain Rodman in that year patented the mode by which all the larger American guns have been cast. Within the core are two water pipes, one inside the other, and like those in Mr Field's boiler, known to so many in this society. Water flows down the inner pipe, which is open at both ends, and rises through the outer pipe, which is closed at the bottom. A perfect circulation of water is thus secured. . . .

"Nearly all the railway wheels in use on the American lines are of cast-iron, chilled on the periphery. It is not merely that these wheels are cheap, but they are preferred to the wrought-iron wheels as used on English railways. I am not now speaking of the engine-driving wheels, but of the carriage and waggon wheels, of from 2 ft. 6 in. to 3 ft. in diameter, although the size is very seldom greater than 2 ft. 9 in. The cast-iron wheels run until they are worn out, and they wear for a long time; whereas the wrought-iron wheels require frequent turning, and, still worse, their flanges soon become worn so thin as to become unsafe, a fact due, perhaps, to the inferior condition of the American lines. It was, however, a long time before the American founders could produce chilled wheels which should be safe under all circumstances; and when it is remembered that they are now employed as the leading wheels of the heaviest express engines working on lines, of which, what we should call the ballast, is sometimes frozen as hard as a rock for two or three months in the year; and in a climate where the mercury is occasionally from 10° to 20° below zero, or 40° to 50° of frost, and when it is added that these wheels do not break oftener than wrought-iron wheels on the best English lines, it must be added that they are as safe as anything can be. In this I am speaking from my own knowledge, extending over a period of ten years, during the whole of which time I was closely connected with the leading American locomotive factories and lines of railway. The founders had to obtain not merely strong iron, in respect of tensile strength, but an iron of considerable toughness, and, besides, an iron that would chill well. As a rule, such iron is only obtained by careful mixing, and it must be sought by long and costly experiment. I do not doubt that iron for excellent chilled wheels, if they were ever required, might be found in England; but I would not run the risk of saying what mixtures would produce it, although I should say Blaenavon cold blast and the Forest of Dean irons would enter into such a mixture, with a little iron like that made at Tinsley Park for hardening.

. . . .

"The next point to be considered is the treatment for making castings malleable. I should have said nothing of this were it not that, although exceedingly simple, it is but very little understood, for it is a very common notion that many and curious 'chemicals' are required, and that there is much mystery in the process. . . It is commonly said that castings intended to be malleableised should be from very hard, brittle iron. It is not exactly because a casting is brittle that it is of the best sort for the malleable iron treatment, but brittle castings contain less carbon than those from grey iron, and so the malleable process does not have to be so long continued to get rid of it. To those who are not accustomed to consider all forms of iron and steel as combinations merely of iron and carbon in different proportions, there is something a little paradoxical in the fact, that a grey iron containing much carbon is tough; a white iron, containing less carbon, is brittle; steel, containing still less carbon, is also brittle; while wrought-iron, containing but little carbon, is very tough. Even to a chemist these facts are not easy to be explained, nor shall I examine them further here, it being sufficient merely to have shown why a white and brittle cast-iron, such as some of the Ulverston iron of which clock bells are made, is the best for the malleable iron process, because it contains less carbon than a grey iron. The castings must be packed perfectly air-tight in layers of powdered ore, and shut up in cast-iron boxes, of which the joints should be luted. . . .

"On the last point named in the earlier portion of this paper—the production of chilled castings—there is not very much to be said. It is for the founder to ascertain, from his practice and from such experiments as he is in the best position to make, which irons will chill and which will not. Of those that will chill, it is important, if the chilled casting have to be put under great strain, that the chill be well blended with the softer iron, instead of there being a distinct line of demarcation. It may be that the best application for chilled castings will be that for chilled shot, which, at far less cost, come nearest to steel. To cast shot in chills, with the best results, it may be found best to subject the iron, just after pouring, to a considerable steam pressure. By simple mechanical arrangements easily devised, a pressure of 100 lb. of steam per square inch, equal to a column of iron upwards of 30 feet high, could be turned instantly upon a casting just poured into a chill mould. The effect would be to secure greater density and uniformity in the casting, and to render it stronger for its purpose. It is well known that 'head,' or a high rising column of metal over the mould, is an important matter in making strong castings, and that, in some cases, as in casting sugar-mill rolls, this head or 'gate' of metal is well churned by manual labour. There can be no doubt that steam pressure would answer the purpose still better, nor that the best mode of applying this pressure might be easily determined.

"The very cheapest applications of iron are in its condition of cast-iron. For some purposes, as for heavy ordnance, it is questionable whether cast-iron is not really equal to wrought-iron and steel. It is certain that comparatively little has been done in this country to improve the strength of large castings, and that, in some cases, wrought-iron has been adopted, without sufficient attempts to meet the requirement with a much cheaper and more adaptable material. It cannot be argued that, in arched bridges, like some of those now erected and in course of erection over the Thames, wrought-iron is equal to cast-iron in its resistance to compression. It is probable that absolutely better and cheaper structures could be put up in cast-iron. It is to be hoped that the careless practices which formerly prevailed of casting large pieces on the foundry floor, and of paying little attention to uniform cooling, have not permanently deprived us of one of the best applications of one of the most important materials of construction."

90. *Boiled Iron.*—From an article on this subject in the "Mechanics' Magazine," Oct. 20th, 1865, we take the following:—"Among the numerous improved processes which have of late years been introduced in the manufacture of iron, few are more interesting or important than that of 'boiling' the metal. To this system, which has been somewhat recently introduced, the ordinary process of decarbonisation in the refinery and the puddling furnace appears to be fast yielding. Pig iron produced in the smelting furnace by coke or coal is converted into malleable iron either by decarburisation in the refinery or oxidising hearth, and subsequent puddling; or it is converted at once in the puddling furnace by the process of boiling, which is equally effective and is now more generally practised. Shortly after the employment of the puddling process, it was found that considerable advantage was gained by mixing some of the crude iron with the refined plate metal. By this means a saving of the expense of refining upon the iron used in the crude condition was effected. Trusting to the decarburising effects of the puddling furnace, it was found that if crude iron, containing a proportion of oxygen and very little carbon, was used, the refining process might be entirely dispensed with. This operation is popularly known as the 'boiling' process, and it has acquired its name from the following circumstances which are attendant upon its working. As, in this single process, all the carbon has to be got rid of in the puddling furnace, a violent evolution of gas ensues, so that, during the period of its disengagement, the fluid iron boils and bubbles most energetically, and thus furnishes an appropriate name for the system. When melted in this operation the pig iron is more fluid by reason of its containing a greater proportion of carbon than the metal from the refinery. A greater amount of labour, too, is required in stirring it about and submitting it to the action of the current of air. There is likewise a greater waste of iron attached to this process than occurs in puddling either plate, or crude iron and plate mixed. The loss, however, is less than in the two operations of refining and puddling. Another unpalatable fact which results from the boiling process is that the superior fluidity of the iron has a more injurious action on the furnace

But, in spite of these objections, the plan of boiling without the intermediate refining process is gradually gaining ground, and for the last ten years there has been a general tendency to adopt this decidedly superior method; in fact, in several places the use of the refinery has been superseded by boiling. Taking this in conjunction with other collateral circumstances, it may fairly be inferred that the time is not far distant when the refining process will be universally abandoned.

"Mr. Fairbairn tells us that in the boiling process, as carried on at the works of Messrs. Rushton and Eckersley, at Bolton, a small proportion of Cumberland hematite ore or peroxide of iron is mixed with the pig iron to be converted. It is found to assist in the process of boiling by supplying oxygen in the molten mass, and in other respects facilitating the process, increasing the yield, and improving the quality of the metal. As regards the first introduction of the boiling process in the iron manufacture, it appears that the credit of it is due to Mr. Hall, of the firm of Barrows and Hall, of the Bloomfield Ironworks, Tipton. Mr. Hall instituted a long-continued series of experiments in remelting and extracting from the scrap and slag of puddling furnaces a quantity of ductile iron. According to that gentleman these experiments led to the introduction of pig iron and the boiling system in the puddling furnace. This is said to have taken place more that thirty years ago, so that we may consider Mr. Hall as the first to introduce the system of boiling, which ultimately dispensed with the refinery, and established the more expeditious process of puddling direct from the pig. Considerable attention has been given to the decarburisation of the crude iron, and many unsuccessful attempts have been made to secure a more scientific and perfect process. The nearest approach to perfection, however, appears to exist in an improvement patented by Mr. James Nasmyth in 1854. This patent has been worked for some years at the Bolton Ironworks, where its constant employment in the puddling furnaces has afforded proof of its utility. As its advantages become known its adoption increases, and it is gradually extending itself among the large manufacturers. The principle of the invention consists in the introduction of a small quantity of low pressure steam into the molten metal as soon as it is fused; 5 lb. steam is *generally* used. As at that high temperature the oxygen of the steam has a greater affinity for carbon than for the hydrogen with which it is combined, or for the iron, the carbon is rapidly oxidised off. The hydrogen which is liberated has no affinity for the iron, but unites with sulphur, phosphorus, arsenic, and other substances which are very prejudicial to the quality of the iron. However minute may be the quantities in which they are present this is always the case, and they are frequently found both in the ores and in the fuel. Besides the chemical part the steam plays with respect to the iron, it also has a mechanical action on it. It is introduced at the bottom of the furnace, and being thence diffused upwards it violently agitates the iron, thereby causing fresh surfaces to become exposed to the oxygen passing through the furnace.

"In carrying Mr. Nasmyth's plan into operation, steam is conveyed from the boiler to a vertical pipe fixed near the furnace door. At the lower end of this pipe is a small tap or syphon to let off the condensed steam and prevent its being blown into the furnace. To the flange of the vertical pipe are fastened a cock with several jointed pieces of pipe, forming in effect jointed bracket pipes, which allow of free motion in every direction; the steam tube or 'rabble' being bent at the end so as to inject the steam on the liquid metal. As soon as the iron in the furnace is melted, the puddler introduces this apparatus, which he moves slowly about in the molten iron, while the steam pours upon it through the bent end of the tube. In about five or eight minutes the mass begins to thicken, when the puddler withdraws the steam-pipe, and the operation is finished in the usual way with the common iron rabble. It is found upon an average that from ten to fifteen minutes are saved by this process in every operation or 'heat,' and that during the hottest and most laborious part of the operation. By the adoption of this simple apparatus the highly carburised pig iron, which is the most free from impurities, is rendered malleable in one furnace operation, without the deteriorating adjuncts of the ordinary refining and puddling process. In this arrangement no deleterious substance can enter into combination with the iron, whilst the mixture of fuel and metal, as in the refinery process, is liable to deteriorate the metal with sulphur, silicum, &c. In short, the new process has a beneficial effect in *purifying* the iron with greater economy than any known process."

91. *Mechanical Puddling of Iron.*—"Nothing," says the Practical Mechanic's Journal, "almost can be cruder or simpler in its theory and first aspect than the operation of puddling, by which iron, in the state of pig or cast iron, is converted into malleable or bar iron; and yet for half a century the operation has stood still in the position in which Cort, its reputed inventor, left it, although from year to year the laborious and unsatisfactory nature of the hand-wrought process by which it is conducted has been admitted and lamented, and attempts to improve it by getting rid of manual labour, or by the substitution of some altogether new process, have successively ended only in readmitting the difficulties of improvement.

"The fundamental idea of puddling was neither more nor less than burning out a large proportion of the carbon, and of some of the other extraneous metalloids or metals contained in the pig iron; and for many years the refinery process—which consisted in fusing the pig iron in a sort of shallow cupola, with an enormous excess of air blast, and running out the *refinery pig* into thick cast iron ingot moulds, so as to 'chill it,' or into water—was deemed indispensable as a preliminary to puddling. This severe comburation was, however, within the last thirty years, found needless in most instances, and that by a proper choice of the quality of the pig iron—or in large works by a suitable mode of working the blast furnace, so as to obtain a good hard gray or mottled pig iron exclusively—it might be dispensed with. But here the progress of improvement ended.

"The puddling furnace itself, if we except Roger's invention of the cast-iron sole, and the method of repairing the interior of the brickwork with a paste of *hæmatite* iron ore mixed with fire-clay, and a few alterations in proportions, size, &c., has remained just as it was in CORT'S day, and the method of manipulation the same also.

"Crude and obvious as its theory at first sight seems—the fact is, that puddling is an extremely curious and not so easily discerned combination of chemical and mechanical forces, or rather methods; and in the very union of these lies the difficulty of improvement, or of any substitution of power for the skilled hand and eye of the puddler.

"*So far as the chemical* part of the process of converting cast into wrought iron, the operation of the refinery was identical with that of the puddling furnace. Carbon, silicon, and perhaps phosphorus, were burnt out, and with them some of the metals of earthy bases oxidized and burnt out also, as the following analyses indicate:—

	Iron from Blast Furnace.	Same Iron from Refinery Furnace.
Iron,	95·26	98·33
Carbon,	2·63	0·87
Silicon,	1·38	0·53
Aluminum,	0·73	0·26
Phosphorus,	trace.	trace.
Sulphur,	trace.	trace.

"Analyses of the slags, or 'tap cinder,' many of which are quoted in books of iron metallurgy, really tell for nothing—a large proportion of their constituents being derived from the fusion of the internal surface of the walls of the furnace.

"This is proved by the results of weighings at Dowlais, given by Mr. Truran in his work on iron. Thus—

Crude iron put into furnace,			2,498 lbs.
Produced	Refinery pig,	2,240	
	Cinder,	325	
			2,567 lbs.

Excess in weight = 69 lbs.

Now as the oxygen fixed by the oxidation of the iron, silicon, and aluminum, is about balanced by the loss of carbon volatilized as carbonic oxide and acid, it follows that most of this excess is due to earthy matter fused off the furnace, and hence that cinder analyses prove nothing. This is equally true for the puddling furnace as for the refinery.

"Calvert and Johnson's researches on the progressive chemical changes produced in puddling, show that these are quite analogous to those which occurred in the refinery. Thus, when No. 3 grey Staffordshire pig iron was the subject of experiment, and the iron in progress of change was taken at successive intervals of time from the puddling furnace and analysed, results such as the following were obtained:—

Pig Iron employed. No. of Sample.	Time.	Amount of Carbon per. cent.	Amount of Silicon per cent.
Iron as put into furnace,	12 noon	2·275	2·720
Sample No. 1,	12·40	2·726	0·915

Sample No. 2,	1·0	2·905	0·197
,, ,, 3,	1·5	2·444	0·194
,, ,, 4,	1·20	2·305	0·181
,, ,, 5,	1·35	1·647	0·183
,, ,, 6,	1·40	1·206	0·163
,, ,, 7,	1·45	0·963	0·163
,, ,, 8,	1·50	0·772	0·163
Puddled bar,	—	0·296	0·120
Rod iron rolled from it,	—	0·111	0·088

So that the carbon is slightly increased at first, and then both it and the silicon steadily burn out, and, as is apparent by the last two lines, much of these continues to burn and work out during the 'shingling' of the puddle balls, and the subsequent rolling of the puddle bars into rod iron. The final results are shown as follows :—

	No. 3. Pig Iron.	Puddle Bar.	Rolled Rod.
Carbon,	2·275	0·296	0·111
Silicon,	2·720	0·120	0·088
Phosphorus,	0·645	0·134	0·117
Sulphur,	0·301	0·139	0·094

These were in some degree confirmed by the composition of the slag from the furnace.

"Thus, chemically, the refinery, the puddling furnace, and the Bessemer converting vessel, all perform the same parts ; but puddling has this peculiarity added to it—that a certain proportion of the fusible slag, the silicate of oxide of iron formed in the process, is kneaded up with the pasty and finally crumbled mass of puddled iron, and plays a highly important, though probably not fully understood part, in determining the molecular arrangement of the wrought iron, when the puddled bar is submitted to the roller.

"This kneading up of wrought iron and silicate, then, constitutes the mechanical element of the puddling process, and appears to be absolutely essential to the result—essential, at least, so long as wrought iron in rolled or forged form shall be considered a necessary structural material, or until steel produced by the Bessemer process shall have taken its place. The chemical part of the process is one—the progress of which requires to be stopped at a given moment—known to the educated eye of the puddler by shutting down the damper, so as to convert the oxydating flame of the furnace into a neutral one. But at this moment the kneading up of the silicate must be complete, so that the metal may be speedily withdrawn, or new and mischievous chemical changes commence; hence arises the delicacy of the puddling process, when stated as briefly as possible.

"By the Bessemer process it is at least doubtful whether regularly fibrous metal can be produced under the roller—that is to say, whether the crystals of the metal can be induced to elongate in the direction of least pressure, arising from the fact that the absence of intercalated slag greatly *reduces the difference* (in internal pressure in the orthogonal directions) of greatest and least pressure within the 'billet,' or mass between the rolls. Homogeneous metal—which is, in fact, but an iron very pure from slag, and with its carbon combined in the state of a 'low steel' or good steel, are the only products of the Bessemer crucible, and for almost all structural use, such products will before very long come to be substitutes of wrought iron. But great as is the increase of ultimate tenacity, steel, as compared with wrought iron, and valuable as it must become, there will ever remain a number of structural purposes for which wrought iron, with its softness, ductility, and high extensibility, must continue to be required, and for the production of which the puddling furnace must continue in use. Puddling, hence, cannot be viewed as an expiring art; and for this reason, as well as from the vast amount of public attention that has been recently drawn to it by reason of the long and embittered disputes between the working puddlers and the iron masters in this country, we have thought it advisable to translate at length two very able papers on the subject of mechanical puddling as practised in France, which have appeared in the *Annales des Mines* very lately, and to place them in a form available to English readers, accompanied by the more important of their illustrations."

The article here alluded to is unfortunately far too long for even an abstract of it to be here given; we therefore refer the reader to the number of the Practical Mechanic's Journal, in which it appears under date September 1st, 1865.

92. *Machine Puddling.*—On the same subject referred to in last paragraph, we take the following from an article in the "Enieer," under date Sept. 15th, 1865. "The earlier stages at least the process of puddling a charge of iron involve operations so

simple that it is a matter for some surprise that they have not long since been carried out by machinery. The constant stirring of a little pond of molten iron is the thing to be done, and a common bar of iron with one end bent down at right angles is the thing to do it with. The necessary motions are in no way complex, and so far very simple machinery should suffice for the operation. The history of attempts at machine puddling runs back nearly a quarter of a century. But it is only within the last year or two that the practical adoption of puddling machinery has been attended with success. It is beyond question that the problem presented to the mechanician was formerly invested with difficulties which modern experience proves to have been more or less imaginary. Too much was attempted, and of course little or nothing done. The paramount idea was that the labour of the puddler should be wholly superseded, and the entire process, blooming and all, effected solely by the aid of steam power. In this lay a great error. There are many processes in the arts which cannot be effected without the very effectual interference of the human arm guided by intelligence, and puddling is pre-eminently one of these. The only available course to adopt is to permit the machine to perform the major part of the hard work, leaving the completion of the process to the man. Mechanism constructed according to this principle has now been at work for some time with excellent results, and the universal adoption of machine puddling is not we think very distant. Mr. Menelaus, of the Dowlais Ironworks, has for some months past been carrying out a series of experiments on a very extended scale, neither the details of which, nor the results, have as yet been given to the world in full. We understand, however, that so far, the latter have been very encouraging. The system adopted at Dowlais is we believe that known as Walker's, in which the iron is exposed to the action of the flame by the rotation and oscillation of the vessel containing the molten metal, which takes the place of the ordinary hearth. At the Wombridge Ironworks, Salop, Mr. Bennett, the manager, has introduced a system of his own invention which we recently illustrated. Mr. Bennett read a somewhat elaborate paper on this machine, and the results obtained from its use, a few months since before the Institution of Mechanical *Engineers;* from which we learn sufficient, even after making every allowance for the fact that the author is also an inventor, to lead us to believe that he has really achieved a very considerable success. The principle on which the machine is constructed is very simple. The ordinary rabble is worked backwards and forwards by a vertical arm outside the furnace, to which it is connected by a notch or gab in the handle, dropped loosely on a pin in the lower extremity of the arm. The arm is cottared at the upper end into a horizontal square slide bar, moving longitudinally through suitable sockets, and is put in motion by a connecting-rod from a long T-iron bar, supported on rollers, and extending over the entire row of furnaces. A crank, driven by a worm-wheel, is so arranged that a transverse as well as a longitudinal motion is given to the rabble, which, working at the rate of about fifty strokes per minute, completely traverses nearly every portion of the hearth. Double furnaces, with a rabble at each side, have been employed with considerable success. In this case the traversing cranks, which make but one revolution for every seventy strokes of the tool, are set at right angles, so that the two rabbles are always working in different parts of the furnace. The entire apparatus is kept clear above the furnace, is well protected from the heat, and out of the way of the men. Mr. Bennett thus describes the method of working the machine:—'When the charge of pig iron is melted, and ready for the commencement of the process of puddling, the apparatus is put into action by dropping the notch in the handle of the rabble on to the pin in the working arm, which is kept continuously in motion by the horizontal reciprocating bar working overhead. The puddler changes his tool from time to time as it becomes heated by simply lifting the notch in the handle off the pin in the working arm, and replacing the tool with a fresh one without stopping the machine; and when the iron begins to thicken, he takes the opportunity of each change of tool to make a few strokes by hand, in order to collect the metal from the extreme sides of the furnace into the centre, which is found to ensure the uniform puddling of the whole charge. The usual time of working with the machine is about twenty-five minutes with ordinary forge pig, the tool being changed five or six times; but with grey iron the time of working is much prolonged. In the latter case the machine is especially s[illegible]e, since the iron keeps in a fluid state much longer, and requires consequently so much more working, which causes the labour to be so much more severe in the case of hand puddling that there is great difficulty in getting the men to work any iron that is very grey. With the machine, however, this causes no increase of labour to the men, and only increases the duration of the process.' So much for the mode of working, now for results. These we may best express in Mr. Bennett's own words:—'With the single furnaces at the Wombridge Works, and charges of 5 cwt., the consumption of coal is 28 cwt. per ton of puddled bar made; but with the double furnace, and charges of 10 cwt., the consumption of coal is only 17 cwt., being a reduction of 39 per cent. The number of heats or charges worked in the single furnace is six, of 5 cwt. each; and in the double furnace, five heats of 10 cwt. each per turn of nine or ten hours. In working the double furnace it is found best to have one puddler only and two underhands, to avoid the division of responsibility that would arise in the case of two puddlers working the same charge of iron.' These facts speak for themselves, and although a vigorous discussion followed the paper we find that no arguments were adduced which materially affected the position assumed by Mr. Bennett. We have no desire to speak of his machine with undue preference—we have selected it as an example of what may be done, not because we believe it to possess any peculiar merits, but simply because it is the only apparatus of the kind, of the working of which any very definite information has been made public. The principles involved in its construction appear to be founded on common sense, and with this statement our praise of the machine must begin and end. But there are other labourers in the field as well as Mr. Bennett, and we see good reason to believe that the day is not distant when the ironmasters of England will be placed in a position superior to any which they have held for years, while the men will feel that in their emancipation from a fearful toil they have advanced by a mighty stride from the condition of well-paid labourers to that of still better paid skilled artisans."

93. *Titaniferous Iron.*—"On the 24th of last month some account was given in this journal of the results of some experiments made by Messrs. D. Hipkins and Sons, of West Bromwich,

some iron, smelted by Mr. Charles Martin's patented process, from the titaniferous iron-sand of New Zealand. Other firms have since been experimenting with specimens of this iron, with results quite as satisfactory as those previously obtained by the Messrs. Hipkins. To the account of the properties of this almost unprecedentedly fine quality of iron which we gave three weeks ago, we may now add that a 'heat' of it can be puddled in sixty minutes, which is just half the time per heat which the process of puddling usually occupies, and that the loss of iron in the process is only one-fourth of the usual proportion of loss. Moreover, this titaniferous iron has the remarkable property of completely resisting the action of hydrochloric acid. The peculiar qualities which give it its great value are doubtless due, in part, to its entire freedom from both sulphur and phosphorus, and not exclusively to the titanium which it contains. Still, it seems to be pretty well ascertained that a small quantity of titanium very greatly improves the quality of both iron and steel, and hence considerable attention is beginning to be directed towards the titaniferous iron ore, or 'ilmenite,' which exists in such vast quantities in Sweden, Norway, and Russia, and also in Canada and elsewhere, and which, while it can be had in this country much more cheaply than the New Zealand iron-sand, which contains only from 9 to 13 per cent. of oxide of titanium, contains not less than 40 per cent. of that oxide. As yet, there are many difficulties in the way of smelting, on the great scale, ores of iron containing so much titanium as the European titaniferous ores contain, but these difficulties will doubtless yield to sufficiently persevering efforts to overcome them. It is not proposed to endeavour to smelt these ores by themselves; all that is contemplated is the admixture of them, in small proportions, with our ordinary English ores. The conditions, however, under which such a mixture can be satisfactorily smelted, have yet, for the most part, to be ascertained."—*Mechanics' Magazine, Dec.* 15*th*, 1865.

94. *Exceedingly Hard Iron.*—"Some years ago M. Gaudin found that by heating iron, tolerably free from carbon, with a small quantity of boron, to a very high temperature, he obtained a product which could not be forged, but which possesses extraordinary hardness. He has now found that an equally hard *metal* may be obtained by adding to ordinary cast-iron in fusion,

phosphate of iron and peroxide of manganese—he does not mention in what proportions. The product cannot be forged, but it casts easily, and is therefore readily applicable to the construction of such machines, or parts of machines, as require in their material extreme hardness rather than tenacity. The metal so produced is, moreover, singularly sonorous, and M. Gaudin accordingly proposes it as a material for bells. He finds that a still harder metal is producible by the addition of tungstein—again he omits to say in what amount—to ordinary cast-iron. He states that this tungstein iron surpasses everything previously known as a material for tools for cutting rocks, and that crystals of it will cut glass as readily as the diamond."—*Mechanics' Magazine, Dec. 22d*, 1865.

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DIVISION EIGHTH.

RAILWAYS.

95. Of the various papers of the year issued in connection with the present division, the most important, certainly that which contains the most novel, if not the most practical proposition, is that read by Mr. Peter Barlow, F.R.S., before the Society of Arts, on the "*Best mode of applying power to propel trains on the Metropolitan and other railway lines, having frequent stations in terminal stations.*" Of this paper we can only find space for an abstract. After referring to the circumstances which prompted him to pay attention to the subject, and showing the loss incurred in the use of locomotive power where the distances between the stations are short, and these stations numerous, from the fact that "all or nearly all the work of the engine is expended in acquiring the travelling speed, and that in fact it has not ceased to accelerate its speed when it becomes necessary to shut off the steam and apply the brakes so as to stop at the next station," the author proceeds to show the advantages arising from the use of stationary engine power. "In terminal stations the use of stationary power will add much to the simplicity of working. At *present*, as the locomotive arrives in front of the train,

it is made prisoner until the train is removed. It has thus to go to another part of the station to be turned on to take in coke and water, and then comes back again to the train it has to take out. These frequent operations not only wear out the road and points and crossings very rapidly, but cause constant stoppages to trains arriving to enter the station. To avoid a portion of this difficulty the locomotives are sometimes run tender first, a mode of working which amounts to an admission of imperfection, and appears to foreshadow a change in the present systems, particularly as the more the traffic increases the greater these imperfections will be felt. When the stations are near together the time required to acquire the speed is so important an element that greater tractive power is requisite to enable a reasonable average speed to be maintained; and the power of the engine is governed by the power requisite to put the train into motion. Thus, the actual power exerted to propel trains of forty tons, every five minutes each way on a railway similar to the Metropolitan, of three and a half miles in length, at the velocity now adopted, would not, allowing one-third lost power, and 15 lb. per ton traction, exceed 214 horses, to obtain which at least ten locomotives, capable of exerting, in the aggregate, a power of 2,200 horses, are required, in consequence of the combined losses from the extra weight to be conveyed; the power to overcome the inertia; and, thirdly, from the engine being restricted from making a fair working speed, these losses being in addition to that of the engine itself from friction, &c.

"Seeing that it is necessary to use such powerful engines to passenger trains where the stoppages are frequent, it follows that the weight of the engine becomes large in proportion to the weight of the train, and therefore, if that weight can be dispensed with, much less power will suffice to give the same amount of speed, or, with the same amount of power applied, a much greater speed will be obtained. In like manner if the weight of the engine is dispensed with the train can be brought to rest in less time by means of the brake and coupling; this, with the increased rapidity with which the speed at starting can be acquired, it follows that dispensing with the weight of the engine would be of very great advantage in the case of stopping trains.

"*The mode of applying stationary power* differs from that hitherto employed, inasmuch as it is not connected from station to station, or connected through several stations, like the Blackwall system, but each has a propelling power independent of the other, although the power may be derived from several stations from one engine. It also differs from the power being used accumulatively, and thus a smaller power of engine is required.

"I will now observe that the result of the experiments on the Whitstable railway, previously referred to, and the examination generally of the subject of motive power, led me to recommend the directors of the South-eastern railway to substitute locomotive, and abandon the stationary engines on that line; and the alteration was attended with satisfactory results, not because there was any serious difficulty in the rope system, except its great weight and length, but because one locomotive was made to do the work of all the stationary engines, and a greater average speed was obtained. One of these ropes was one mile seventy chains in length; and on the Blackwall railway the rope was above three miles in length to carry passenger traffic. Great mechanical skill and good workmanship is indicated by the fact that such a piece of machinery could be kept in order for any length of time, because the actual weight put in motion, and inertia to be overcome, in addition to the train, was much greater than that of a locomotive, besides the friction of 500 sheaves. These cases, however, prove that no practical difficulty or liability to derangement is likely to arise in the use of a rope for 150 or 200 yards only, as is now proposed; and it may be here remarked that although ropes have been superseded by locomotives in many cases, yet that still a larger amount of traffic is carried on by ropes, and in one important instance, viz., Glasgow, the locomotives have been again abandoned for the rope on an incline of 1 in 43 for one mile fourteen chains, used for passenger traffic.

"The mode which first occurred to me of applying the stationary power for the present purpose was, by Sir W. Armstrong's hydraulic principle, to give motion to a rope, which system has the advantage that one engine can be made to do the work of several stations by a water main laid along the line. Another form of propeller, very simple in its action, but requiring an engine at each station, is the descent of a weight raised by a small engine constantly at work.

"A weight of forty tons raised 30 ft. every two minutes and a half would propel a train of forty tons more than one mile and a quarter on the level before it came to rest; and a stationary engine of 48-horse actual power, allowing one-third loss, would be sufficient to run forty ton trains every five minutes each way, allowing for the loss from friction and the power required to bring the weight to a state of rest, which latter loss would amount to 10 per cent. of the power. The cost of working such an engine, including repairs, would not amount to £2 10s. per day, so that the cost of train per mile would be under 2d. The trains may also be propelled on the atmospheric principle, either by the old plan of a pipe, or on Mr. Rammel's plan of a small tunnel; and as the power is required only for a short distance, there will not arise the difficulty from friction and leakage which has hitherto been experienced in these modes of traction.

"In another form of propeller suggested which is specially adapted to frequent trains, the accumulation of power is made in the boiler. Driving wheels and cylinders, similar to a locomotive, are used to propel a rope for the required distance. The total weight of moving machinery will not in this case, including the rope, exceed four tons. A duplicate of every part, including the boilers, would be provided, and as there is an interval of eight hours' rest in each day, sufficient to replace any part which might be out of order, I submit that such a piece of machinery may be considered nearly safe from derangement. A propeller of either kind, it is suggested, could be used advantageously on railwsys worked by locomotives for the purpose of starting trains from stations situated at the foot of inclines, where now locomotives, although generally master of their work, frequently fail in surmounting the incline, thus leading to loss of time and danger.

"In conclusion I will observe that it is difficult for the author to describe a new suggestion without a bias in its favour, but I have endeavoured to lay the comparative merits of stationary and locomotive power fairly before the meeting. The subject is so important in its influence on the value and extension of metropolitan railways, that I offer it for discussion without venturing to give a decided opinion of my own, until I hear the views of those eminent engineers who have devoted their attention to the subject of the motive power, which I hope will be expressed on this occasion.

APPENDIX.

The formula used in calculating the oscillation is:—

$$v = \frac{\sqrt[2]{P \times T \quad T}}{\frac{1\ 2240}{T}} \qquad S\ 16\tfrac{1}{3}$$

P being the traction power.
T length of train in pounds.
S length of the plane.
f friction of the train per ton.

Velocity given to a train of 40 lb. to 4,000 lb., falling 600 ft. or 8,000 ft. fully 300 ft., the friction being 15 lb., will be:—

$$\sqrt[2]{\frac{(8{,}000 - 600)}{89{,}600} \quad \underline{30\ \times}}$$

$$\sqrt[2]{\frac{(8{,}000 - 600) \qquad 300 \times 16\tfrac{1}{3}}{89{,}603}} = 27 \text{ miles per hour.}$$

The power exerted will be for five-minute trains,
8,000, fully 300 ft. in two minutes and a-half.

$$\text{or } \frac{8{,}000 \times 300}{2\tfrac{1}{2}} = 940{,}000 \text{ in one minute.}$$

$$\frac{940{,}000}{33{,}000} = 28\tfrac{1}{2} \text{ loco. power} \times 5 = 142{\cdot}5.$$

$$\text{add one-half} \quad . \quad . \quad \underline{71{\cdot}25.}$$
$$214{\cdot}75."$$

96. *Narrow-Gauge Railways.*—At a meeting of the Inventors' Institute, as reported in the "Scientific Review," June 1st, 1865, the following paper was read by Mr. Charles Easton Spooner, C.E.:—"The object of the paper which I have the honour to submit to the members of this valuable Institute is to discuss the subject of narrow-gauge railways, explaining the necessity of their general use, their economy in construction, their utility in certain districts as 'feeders' to through lines, and their adaptation to passenger as well as to general traffic

"The introduction of railways on a narrow-gauge, and worked by locomotive power, is a growing necessity, for opening districts where lines connecting one through line with another are either impracticable, or would be so costly as not to justify the outlay required for their construction; also in mountainous and mineral districts, where their application would be the greatest possible boon to the public, and the means of giving to districts railway communication that, on the parliamentary-gauge, would be too expensive ever to be made. It is in these latter districts that their application would be especially useful, inasmuch as with narrow-gauge lines of 2 ft. 6 in., or from that to 2 ft. 9 in., curves of three or four chains radii can with facility be made, and by this means tunnels, viaducts, and heavy earthworks are avoided, which on the broader gauge would be inevitable; and, at the same time, there is no necessity on short lines of this kind for any very great amount of speed, which is imperative on 'through lines.'

"It is found that the various gauges of railways in different parts of the world are:—In the United States of America, 6 ft. and 4 ft. $8\frac{1}{2}$ in.; South America, 5 ft. 3 in.; Central America, 4 ft. $8\frac{1}{2}$ in.; Austria, 4 ft. $8\frac{1}{2}$ in.; Australia, 5 ft. 3 in. and 4 ft. $8\frac{1}{2}$ in.; Belgium, 3 ft. 8 in. and 4 ft. $8\frac{1}{2}$ in.; Canada, 5 ft. 6 in. and 4 ft. $8\frac{1}{2}$ in.; Cape of Good Hope, 4 ft. $8\frac{1}{2}$ in.; Denmark, 4 ft. $8\frac{1}{2}$ in.; England, 7 ft., 4 ft. $8\frac{1}{2}$ in., and 2 ft.; Egypt, 4 ft. $8\frac{1}{2}$ in.; France, 4 ft. $8\frac{1}{2}$ in. and 3 ft. 4 in.; Ireland, 5 ft. 3 in., 6 ft. 2 in., and 4 ft. $8\frac{1}{2}$ in.; Italy, 4 ft. $8\frac{1}{2}$ in.; India, 5 ft. 6 in. and 4 ft.; New South Wales, 4 ft. $8\frac{1}{2}$ in.; Norway, 3 ft. 6 in. and 3 ft.; Prussia, 4 ft. $8\frac{1}{2}$ in.; Portugal, 5 ft. 6 in.; Russia, 5 ft.; Sardinia, 4 ft. $11\frac{1}{2}$ in.; Spain, 5 ft. $5\frac{15}{16}$ in.; Scotland, 4 ft. $8\frac{1}{2}$ in.; Switzerland, 4 ft. $8\frac{1}{2}$ in.; Sweden, 3 ft. 6 in.

"The sections (not here given) show the Festiniog Railway on a 2 ft. gauge, and a corresponding or comparative section of a line which was made to and from the terminals for the same traffic on the ordinary gauge of 4 ft. $8\frac{1}{2}$ in., such section having been carefully taken, with maximum curves suitable for that gauge, for the like speed on the same radius of curve, and the centres of gravity of the locomotive and carriages of one gauge *brought* to the same as that of the other, and with a proportionate weight of train, the same speed might be attained with equal safety. For instance, as the radius of 2½ chains curve from A to B (not here given) on gauge of 2 ft. 6 in., with wheel base of 5 ft. from centre to centre of axle of carriages, is to A C on radius of 5 chains on the same gauge, with 10 ft. from centre to centre of axles, so is A B radius of 2½ chains on 2 ft. 6 in. gauge to radius A D of 10 chains of 5 ft. gauge and 10 ft. centres, as per parallel dotted lines shown by the versed line *f g* on 2½ chains radius of the chord *n i*, equal to *f g* of chord *m n* on 10 chains radius, or half that of *f g* on the radius of 5 chains and 10 ft. centres. It would appear that, with a succession of small radii curves, a train might be running on three curves at one time, and that in consequence a relaxation of speed would be incurred, caused by the drag binding the wheel flanges against the inner rail of curves, but the result of experiments made give little or no perceptible difference in the speed on passing over such curves.

"For practical purposes, it is not necessary that an exact proportionate size of carriages and trucks should be maintained; it is sufficient if they are about one-fourth the weight, and carry one-fourth the bulk or load of those on a 5 ft. gauge, care being taken that the centre of gravity be brought as low as possible, and that the maximum speed be limited to a less rate than that of a 5 ft. gauge. Very heavy loads are drawn with locomotives of small diameter driving wheels connected, and, from their shortness, a weighted train is easily started.

"Fig. 5 (not given here) represents the same centre of gravity of carriages or trucks for 2 ft. 6 in. gauge, and 5 ft. gauge, as per equilateral angles marked *a b c*. On the Festiniog Railway, of 2 ft. gauge, the passenger carriages are arranged as per dotted lines, which gives an excessive overhanging and rather awkward appearance.

"The Festiniog Railway was made under an Act of Parliament passed in 1832, and built to a gauge of 2 ft. The traffic was, until within the last eighteen months, worked with horses. For many years it was the wish of my father (the company's late engineer) to use steam power, but he met with little encouragement as to the practicability of constructing suitable locomotive engines for so small a gauge. It was only from the constantly-increasing traffic, and the necessity of affording the country passenger accommodation, that it became essential to take the steps which led to this successful issue. Careful measures were entered upon for this purpose, which resulted in the construction of two trial engines, made by Messrs. England, and the experiment proved so successful that the company was enabled to accomplish the end they had so long desired. At the present time they work the traffic with these engines and two spare ones, and they have also made their line suitable for passenger traffic. The Government Inspector, Captain Tyler, R.E., who, with his usual ability and energy of purpose, tested this little line and the locomotives to the utmost, complimented the company on the efficient state of their railway. In his report to the Board of Trade some additional appliances were required, which having been made the company obtained the sanction of the Board to open their line for passengers. This line, of 13¼ miles in length, has a difference in level between the termini of 700 ft., having a continuous average grade of 1 in 92 for 12¼ miles of its length. The exertive power is one way only—from Portmadoc (the great slate depot for shipment) to the upper terminus. The down traffic is entirely by gravity. During the last eighteen months the engines have run over a distance of 60,000 miles without leaving the rails. The locomotives are made to the same centre of gravity as those used on the Great Western Railway; three of these weigh 7½ tons each, and one 8 tons in steam. The engine has two pair of wheels coupled, of 2 ft. diameter; cylinders 8 in. in diameter, with a length of stroke of 12 in., and having a maximum working pressure of 200 lbs. to the square inch. The passenger carriages are 6 ft. 6 in. high in the centre, 6 ft. 3 in. wide, with 1 ft. 6 in. diameter of wheels, and 4 ft. 6 in. centres from wheel to wheel, having a cushioned-back partition inside from end to end. The seats are brought immediately over the wheels, and passengers sit back to back, the arrangement being such as to bring the centre of gravity as low and as central as possible. The floors of carriages are eight inches above the rails, consequently no platforms at stations are necessary, and passengers get in through doors at both sides. Open cars on the same principle, with aprons for bad weather and straps in fair weather, are also in use. It is an interesting and novel sight to see one of these little engines, with a train 120 yards in length, running up gradients of from 1 in 70 to 1 in 180, at a speed of about 12 miles an hour, round curves varying from 2 to 30 chains radius, hugging the hill sides through some of the most beautiful scenery in North Wales, the engine in its passage, when going through some of the cuttings, being occasionally on three curves at one time.

"Where there is a limited amount of traffic, and no necessity to use great power to do that traffic, nor to execute the heavy and costly works required in the construction of the broader-gauged line, why should such expenses be unnecessarily incurred; or, in other words, why make use of a horse to do the work of a pony? While so much discussion has taken place at various times as to break of gauge, and on the subject of adopting one uniform gauge for through lines in this country, it is strange that the policy of lateral branches on a small gauge has either been considered impracticable, or altogether ignored. In maritime locomotion will be seen in daily use vessels, from the small river boat to that of a line-of-battle ship, varying in size and power with the required traffic, local position, the size of rivers, lakes, channels, and seas, as under the peculiar circumstances is found most applicable and beneficial. The question, then, arises, Why not make the same useful and reasonable practice applicable in our railway system? Captain Tyler remarks, in his paper read at the Institute of Civil Engineers on 'The Festiniog Railway,' 'The employment of locomotive engines on this little railway, and its opening for passenger traffic, were not only highly interesting experiments, but were likely to be followed by important results. Although there were still, doubtless, numerous districts where railways on a gauge of 4 ft. 8½ in. might be profitably made, yet there were also many others in which lines of cheaper construction were required. With a narrow gauge, lighter rails and sleepers, less ballast, and cheaper works generally might be adopted; sharper curves might be laid down, very heavy gradients, particularly in mountainous regions, might be more easily avoided, and lighter engines, with lighter vehicles, might be made to do all the work where high speed was not demanded, and where the traffic was not heavy.

"'It was, however, illegal at present to construct any passenger lines in Great Britain on a narrower gauge than 4 ft. 8½ in., or in Ireland than 5 ft. 3 in.; consequently, it would appear to be desirable to obtain the repeal, or at least a modification, of the provisions of the Act 9 and 10 Vict., cap. 87, which regulated the width of the gauge of the passenger lines, as there was now an increasing demand for railways of a minor class. Many coal and mineral lines on a less gauge than 4 ft. 8½ in. were in use, and others were projected with ultimate views of passenger traffic, and it would be advantageous if some narrow gauge were recognised.'

"It may be argued that a break of gauge would incur a change of passengers and luggage at junction stations; this is true, but is it not the common practice on all lines, even where there are the same interest and the same gauge? And further, it may be said that heavy mineral traffic and mercantile goods would have to be shifted from the trucks of the one to those of the other, to the damage and loss to the public or risk of the railway companies. As to mineral goods, it is true they would have to be shifted, and there would be the cost of so doing; but the raw material cannot receive any very great injury in the operation. As regards mercantile goods, it is the common practice to detain trucks at the different stations for delivery of miscellaneous goods, and trucks are often detained in order to fill or make up a load; but if none of these answers could be brought to bear in extenuation, the disadvantages are but insignificant when compared with the large benefits that would be secured to the public by the construction of narrow gauge lines in peculiar districts, and as feeders to the main or through lines, and which it is obvious will be followed by a general increase of traffic spread over all main lines in the United Kingdom.

"As to consumption of fuel, it is found that between seventeen and eighteen hundred-weight is used daily on the Festiniog Railway, with trains running at an average speed of eleven miles an hour, which, on the weight of trains conveyed during the year of goods and passengers (including weight of carriages and trucks) taken *up* the line from Portmadoc to the quarry terminals, on 56,875 tons over ascending grades, the whole distance, including *shunting* at stations, was three-quarters of a pound per ton per mile; or, if taken on the traffic of slates, goods, and passengers, of 81,400 tons, the fuel consumed was half-a-pound per ton per mile.

"It would be advisable that a somewhat wider gauge should be given than two feet, so as to have a greater width of framing for boiler, fire, and smoke-box, and to be two or three inches higher from the rails than the engines used on the Festiniog Railway, which are somewhat confined for room, and that the engines should be made with three pairs of wheels; also that the trailing-wheels should be of broad tyres, without flanges for the purpose of steadying the engine. By this arrangemenent ample room would be given for the connecting and eccentric rods; it would facilitate lubrication, and ensure a very perfect and powerful locomotive. In conclusion, I believe, from observations made, that a 2 ft. 6 in., or a 2 ft. 9 in. gauge, would be one most suited for the description of lines here set forth.

"Captain Tyler, R.E., in his report on the 'Festiniog Railway' to the Board of Trade, stated, 'The adoption of the locomotive power upon this little line is a very important, and has, evidently, been a very successful experiment. The cheapness with which such a line can be constructed, the quantity of work that can be economically performed upon it, and the safety with which the trains run over it, render it an example which will undoubtedly be followed sooner or later in this country, in India, and in the Colonies, where it is desirable to form cheap lines for small traffic, or as a commencement in developing the resources of a new country.'

"With locomotive engines of 2½ ft. driving-wheels, for a 2 ft. 6 in. gauge, which, as compared with 7½ ft. driving-wheels, or (as 7½ ft. circumference is to 23) with three revolutions to one, it will appear there would be three times the friction on the pistons, piston-slides, and the tyres of the wheels; but practically this is not the case, as the friction caused by the greater weight of engine of the broader gauge is, in fact, counterbalanced; also the wear and tear of the rails and line for the same reason is greater."

97. *Maintenance of Railway Rolling Stock.*—"On another page (see the number of the 'Engineer' for May 19, 1865) we give a searching analysis of the question of railway carrying stock,

with a plan for adapting it to the constantly increasing demand for heavier and more voluminous loads, in conformity with the extension of modern traffic, which year by year is increasing the size of our merchant vessels for ocean transit. We commend it to the thoughtful attention of our railway readers.

"While it was in type we saw a notice of a forthcoming paper at the Institution of Civil Engineers, on the Maintenance of the Carrying Stock of the Northern and Eastern Railway, with voluminous tables, giving, we presume, the age of every separate vehicle and engine as accurately as a peerage. The momenclature of Captain Mark Huish will of course be brought into play under the assumptive title of 'Rolling Stock and its Life,' as though the stock had really attained to the condition of perfect rolling, like true wheels, and not like garden rollers, a compound of rolling and sliding, and as though there could be anything 'lively' in the inert masses of structure which sometimes refuse to move down an incline of 1 in 75, unless pulled by the engine. We would earnestly suggest to the railway authorities, who, in opposition to Captain Galton and others, believe that existing railway wheels and axles are perfect, to study the history of Crosskill's clod-crusher. That was a kind of garden roller, set round with spikes like those on the maces of Gog and Magog in Guildhall; in short, a revolving harrow formed of a single cylinder. But this obstinately persisted in pulling up the horses by excessive friction. So Mr Crosskill, like a sensible experimentalist, divided it into two halves, and then it was better; then he quartered it, and it was better still; and, finally, he divided it into as many slices as there were rows of teeth, and these possessed the maximum of advantages.

"It is true that the garden roller, called by courtesy a pair of railway wheels, is not a continuous roller, having only two ends pretending to be wheels, with the middle cut away. But these ends are as obstinate and unyielding as Crosskill's original clod-crusher, but instead of crushing clods they crush themselves and the rails they gride on. Whether this paper is the stereotyped railway production, that gives us class and order, as though the tree of railway knowledge had been plucked, and there was nothing more to find out, or whether it be a sound philosophical *paper,* taking in the whole commercial and mechanical question, having regard to the future, remains to be seen. For our part we regard existing railways as being in much the same position that stage coaches were in previous to their advent, showing great skill and care in their arrangement and management, but becoming utterly useless with the advent of better things. To talk of the present railways and their equipments having anything of the character of permanence is an absurdity, and we are quite satisfied that no great time will elapse before a new class of lines is called into being, especially kept for passengers at the highest rates of speed, and with all the appliances that mechanical philosophy points to and railway bureaucracy resists. A catalogue of to-day, giving a list of all the travelling furniture of a line, will in half a dozen years be as obsolete as the dowry of a Lima lady in the revolution which took away Peru from Spain, in which everything is enumerated,—four-post bedsteads, ancient couches, and all that came from Spain with the *Conquistadores*, summed up with all the shoes, slippers, stockings, and brocade robes and hooped skirts, added to the family property as the three hundred years rolled on.

"The value of the railways will consist chiefly in the land they cover, just as land in the city of London is all in all, and the buildings, unless modern, only an incumbrance—the land being worth, as late sales testify, some £40 sterling per square foot, and on which nothing less than palatial buildings can be afforded a location. and which only merchant princes can afford to occupy. Even these existing railways will have to pale their influence in the presence of new ones, unless they keep pace with the coming times. We know how large a body of railway men there are in the House of Commons, and how they band themselves together, far closer than the Irish Brigade, to make a close corporation of their *imperum in imperio;* but all that will be written down amongst the things that were, whenever they shall become too prominent and obstructive. They would willingly be the despots of Commerce, with the Clearing-house for their council chamber, and practise all the abuses to which irresponsible power is prone; but they cannot put off the inevitable law of progress. When we get our report of the 'Maintenance Paper' we shall deal with it."—*Engineer.*

98. *On Gas Lighting in Railway and other Carriages.*—On

this subject a paper was read by Mr. W. Dalziel before the "London Institution of Foremen Engineers:"—"The reader commenced by stating that the subject of artificial illumination is a question that has engaged attention from the very earliest periods, and the advantages accruing to mankind from having the means of obtaining a good light are too well known to need any comment from me. We are now, said the writer, able to travel from one point to another with great facility, and to reach Glasgow from London in 13 hours; but in a journey of that duration we have to submit to many inconveniences, and not the least is that of a bad light, supplied to us from dirty oil lamps. To remedy this state of things several gentlemen have turned their attention to the lighting of railway and other carriages with gas, but the great difficulty has hitherto been the want of space for carrying a sufficient quantity of gas for long journeys.

"The most successful of those who have attempted the lighting of carriages with gas, has been, I believe, Mr. Newall of Lancashire. That gentleman has at the present time in operation on several railways (for short journeys only), an apparatus consisting, in the first place, of an india-rubber bag, of much the same appearance as an accordian bellows, which, when inflated with gas, opens out to its full extent, and then, as the gas is burnt, closes gradually by its own weight, until the gas is consumed. This bag can be placed on any part of the train or carriage, or in a compartment of a brake van, the latter plan being generally adopted by the various railway companies who have used this plan of illumination.

"When the bags are placed in a brake van, the service-pipes are run along the roof of each carriage, the one carriage being connected to the other by means of india-rubber tubing and union-joints, so that the carriages can be connected and disconnected at pleasure. Attached to the service-pipes are bracket burners, let into the carriage tops for the purpose of illuminating the interior. When all the fittings are complete in the various carriages, the bags are inflated with gas in the following manner:—

"There is placed, in any convenient spot, a large receiver, which is supplied with water from a height (say 30 ft.) by means of a pipe and stop-valve. Another pipe and stop-valve are connected to the receiver, for the purpose of supplying it with gas. There are also two outlet pipes, fitted with stop-valves, one for water and the other for gas. The outlet-pipe for the gas being carried to the place required for charging the india-rubber bags, a hose pipe is made to connect the bags with the pipes from the receiver. Before filling the bags with gas, it is necessary to expel all the air from the receiver, so as to prevent a possibility of an explosion. To effect this thoroughly, the valves of the outlet gas and inlet water are opened until the receiver is filled; then both are closed, and the outlet water and inlet gas are opened, the vacuum formed by the receding water being filled by the gas from the inlet gas pipe. When the water is all withdrawn from the receiver both valves must be closed, and the connection made with the gas bags, the water-supply and gas-discharge valves being also opened. The water will then rush in, forcing the gas into the bags. When the bags are filled, care must be taken to turn off the valves immediately, or the bursting of the bags from the pressure given by the column of water will follow, the bags not being made to stand much pressure beyond that required for burning. The bags being now filled, all is ready for lighting.

"By this plan, for every cubic foot of gas required, one cubic foot of room is needed, the column of water being merely used to facilitate the charging of the bags with gas. If we suppose a train of 20 carriages to be going from London to Glasgow, it would require at least 60 lights, each light burning 3 feet per hour. To supply this quantity of gas, the sole use of 2½ vans, measuring 20 feet long by 7 feet wide and 6 feet high, or a space equal to 2,340 cubic feet—or, in fact, one-eighth of the whole train—would be required to store the gas. Another weak point is the liability of the bags to become injured at the corners, such injury being caused by abrasion and the wear and tear of alternate motion. There is also another objection, which consists in the use of water in charging. In using water at a pressure for forcing gas, a large quantity of the illuminating qualities of the gas are absorbed, and the light is rendered very poor. A yet further objection should not be overlooked, viz., that when the bags are charged with gas, if they were allowed so to remain for a number of days, they would in all probability become very dangerous *machines, from* the fact that air would penetrate through them, and take the place of an equal quantity of gas, leaving the contents a highly explosive compound.

"There have been several other plans suggested for the lighting of railway carriages with gas, but not having been able to find out where they have been at work, I am unable to speak with certainty of their merits or demerits. Some are much the same as the gas bags, and some are intended to work high-pressure gas. I have copies of the specifications of two patents, with drawings, &c., which may be examined by yourselves.

"It appears to me that gas bags are the best means of railway carriage lighting hitherto in the field, but that there are too many strong objections to their use for them ever to become extensively employed. What is really wanted is a vessel that will carry a large quantity of gas in a small space, and give it out for consumption with uniformity.

"I have no doubt you have all heard of the High-Pressure Portable Gas Company, which was started in London many years ago, but when I tell you that there was no difficulty in obtaining at that time high-pressure gas, but that their difficulty consisted in giving an uniform light, you will understand why the Company failed. Their mode of giving light was by means of a peculiarly-constructed cock, which required constant attention and care to keep a regular flame. Now anything that wants much attention will not do for a railway company; therefore it was necessary to construct something which should be at once self-acting and effective, and which would give an uniform light from a high-pressure holder, no matter what the pressure within it might be, whether 5 lbs. or 500 lbs. per square inch.

"Seeing that the bags were not the best appliances possible, I set to work to try if I could not devise something better, and the results of my labours have been that I have now at work on the South Eastern Railway a carriage fitted with apparatus for regulating the pressure of gas with a high-pressure chamber or holder, the cubical contents of which is 8¼ feet. This holder, when charged with gas to a pressure of 135 lbs. per square inch, supplied two No. 3 burners for a period of 16 hours, giving an uniform light the whole of the time.

"Let me now describe the manner by which this is effected. I have two wrought tubes, 7½ inches bore by 14 feet 6 inches long, with the ends welded up. These are fixed on the bottom of the carriage, and are connected by means of a small pipe to the high-pressure holders. There is an inlet and an outlet pipe. Connected to the outlet pipe I have a regulator fixed. This latter consists of a common gas holder, working in water, the water forming what is known as a hydraulic joint. The regulating holder has an inlet and an outlet pipe, the outlet pipe being carried to the burners in the carriage, and the outlet pipe of the high-pressure holder connected to the inlet pipe of the regulator. Fixed between the inlet of the regulator and the outlet of the high-pressure holder is a slide valve, worked by a lever. The port of the slide valve is of a V shape; and the lever being connected to the regulating holder by means of two rods, when the regulating holder rises it depresses the valve and closes the port; and, on the contrary, when it descends, it lifts the valve and opens the port.

"When you charge the high-pressure holder with gas, the gas passes through the high-pressure holder into the regulating holder, and as the regulating holder rises it gradually closes the port; and when the port is closed you continue to charge until you get any desired pressure. When this pressure is attained, all is ready for lighting.

"The regulator works as follows:—When the gas is consumed, the regulating holder descends and opens the port, and admits a fresh supply of gas from the high-pressure holder, and continues so to act until all the gas is abstracted from the high-pressure holder, the regulator insuring an uniform light the whole of the time.

"The high-pressure holder is charged by means of a force pump, worked by a steam engine, pipes being laid from the pumps to convenient places for connecting the carriages, the connecting media being lead pipes and 'unions.'

"By my arrangement it is thus possible to fit up a carriage with high-pressure holders (every carriage to carry its own) to hold sufficient gas for the supply of two No. 3 burners for 60 hours; or, with the same space at my disposal that is required for gas bags, I could carry ten times more than my present system, and give an uniform light the whole of the time.

"It *will perhaps still* be said, What are the main advantages of the pressure plan over the present system of bags? I answer that:—First,—you may carry the same quantity of gas in one-tenth the space required for the bags. Second,—That the apparatus, being made of iron, is not likely to fail, either by giving a little too much pressure or by being over-worked. Third,—All the holders being required to stand a great pressure, there is no chance of the air getting in and making the contents explosive by the operation of the law of diffusion."

99. *Railway Breaks.*—"In a paper on the subject, in *Cosmos*, M. Flammarion calculates that if a common train, going at the rate of 40 kilomètres per hour, or 12 yards per second, were stopped instantaneously, the passengers would experience a concussion equal to that of a body falling from a height of 19 feet; they would be hurled against the sides of the carriage with a force equal to that they would be exposed to in falling from a window on the second floor of a house. If the train were moving at the rate of 50 kilomètres per hour, they might as well jump from a height of three pair of stairs; and an express train would, in point of fact, make them fall from a fourth story. Instantaneous breaks are, therefore, not to be thought of, and, fortunately, have not been invented; the impetus of a train, even at half-speed, being much too great for any mechanical means of instant stoppage. A break, though instantaneous in stopping wheels, will still leave the train to go forward a little as a projectile, so that there is no fear of any break ever to be invented, perhaps, being too instantaneous in imminent danger. M. Achard, a civil engineer, according to *Galignani*, has invented an electric break, which simply consists in keeping the break or shoes, which lie opposite the wheels, away from them by means of an electric current; as soon as the latter is interrupted, the break falls upon the wheels, and the speed of the train is slackened in consequence. All the engine-driver has to do is to put his hand on a small interrupter, having much the appearance of a door-handle, and this takes him less time than giving the alarm by means of the whistle. Two small Bunsen's elements are employed to produce the current, which are kept in a wooden box."

100. *The Whitehall and Waterloo Pneumatic Railway.*—"It is said the works of this proposed railway will be commenced immediately on the necessary Parliamentary powers being ob-

tained. The proposed line will commence at an open station to be formed in Great Scotland-yard, and be continued in brickwork under the Thames Embankment to the river; across which it will be carried in a water-tight iron tube, encased in cement concrete, laid and fixed in a channel dredged out of the bed of the river. From the river the line will be continued in brickwork under College-street and Vine-street, to a station convenient for the traffic of the York-road and the Waterloo terminus of the South Western Railway. The steepest gradient will be 1 in 30. The trains will be worked to and fro by pressure and exhaustion alternately, and at intervals of from three to four minutes from each end; a frequency of despatch hitherto unattempted. The carriages will be as commodious, as well-lighted, and as completely fitted for the comfort of the passengers, as those of the Metropolitan Railway. The iron tube will be made by Messrs. Samuda, and the laying of the tube and other works will be undertaken by Messrs. Brassey and Co. The principle upon which the line will be worked will be the same as that adopted on the experimental railway in the grounds of the Crystal Palace. The machinery will be on the Surrey side, at the York-road station. The whole of the works are to be completed in twelve months from the date of the commencement. The cost of the undertaking will be about £130,000. The pneumatic system, by which air is applied to railway propulsion, and the incumbrance of the locomotive is got rid off, differs materially from the former atmospheric system. Under the new system, the train is wholly within a tube or covered way, through which it is rapidly propelled by the pressure of the air behind it, so that not only are all the difficulties attending the continuous valve and the consequent leakage avoided, but the advantage of working with greatly reduced pressures, and with proportionate economy, is obtained. Thus, while the old system necessitated a pressure of from 120 ounces to 160 ounces per square inch to move the train; under the new, a pressure of three ounces or four ounces per square inch is found sufficient. Indeed, in its present form, the pneumatic system is simply an adaptation of the process of sailing to railways; the wind being produced by steam-power, and confined within the limits of a tube."

DIVISION NINTH.

SHIPS.

101. *On cleaning Iron Ships Afloat.*—The most remarkable feature of late years in what is called "Marine Architecture," is the substitution of iron for wood. Numerous as are the advantages derivable from the use of iron, ships built of it always labour more or less under the great *dis*advantage, their liability to receive a deposit—on the parts under the water line—of molluscous animals, bringing about what is technically termed the "fouling of the ship's bottom." So serious a matter is this, involving loss of speed in the sailing of the ship, that all most every means have been adopted to prevent the attacks of these animals, and to secure the clean state of the ship's bottom, so essential to her good sailing condition. In a paper read before the Scottish Builders' Association, Mr. John Harrison goes pretty fully into the actual history of the animals which attack iron ships, the modes in use to prevent these, the reason of their failing, and of his own method of getting rid of the difficulty. After noticing the use of copper—which is by far the best material which is in employment—Mr. Harrison points out that "It is not the poisonous nature of copper which prevents these creatures from fixing upon it, for indeed they do fix upon it, as fast as upon any other substance, but it is its rapid oxidation or scaling off which prevents their remaining after they do fix. It is, therefore, my opinion that, if ever a covering is found to protect an iron ship from fouling, it will be a pigment of some sort that will possess the same property as yellow metal or copper—namely, of scaling off and continually cleaning itself.

"It was in this direction that I first extended my inquiries, and my proposal was to cover the iron plates with copper to a considerable depth before building the ship, and to give the two metals a metallic connection, so that there should be no galvanic action evolved between them. These two metals, however, have no affinity. They will not weld together as iron will, and, therefore, it was with considerable difficulty that I succeeded in uniting them, By a certain chemical process, however, it was done, as you will see from some small samples on the table. Whether vessels may ever be built in this way I do not know, there being still some mechanical difficulties in the way which I have not as yet been able to remove. But on this question I will not dwell, for although prevention is said to be better than cure, the question of prevention is as yet a *questio vexata* on which not two are found to agree, but which, in the absence of facts, may continue to be a fair field for experiment and speculation.

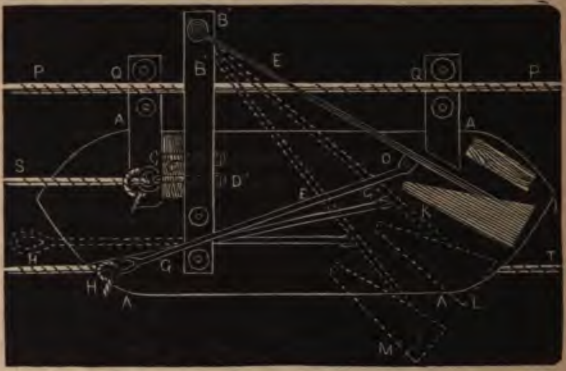
"Let us, therefore, now look at another phase of the subject, namely, since we cannot prevent these colonising fishermen from squatting on our property, what is the best way of ejecting them? I answer at once, by mechanical means alone. This, in my opinion, is the most effective plan, and the cheapest. Many attempts have already been made in this direction. Some shipmasters have tried the friction of a chain on the bottom, others a series of wooden bars with pieces of iron upon them. One machine, at present in use in the navy, is called a 'hog,' and consists of a circular brush, shaped like a barrel, and which they cause to revolve beneath the vessel longitudinally from stem to stern. Another machine has been tried in Liverpool, consisting of a rope ladder, the steps of which are broad pieces of wood, one side being covered with bristles, forming a series of brushes, while on the other there is a piece of iron forming a series of scrapers. This is placed round the vessel, and is wrought by a sort of see-saw motion, rubbing up and down.

"I have reason to know, however, that neither of these plans have given satisfaction, and whoever has examined the degree of tenacity with which these creatures cling to the iron, must know that it is not the soft persuasion of a brush, nor yet even a gentle rub, that will induce them to loose their hold. Nothing, indeed, but a sharp steel edge, equal to that employed by the hand, can ever make any impression upon them.

"The mechanical appliance for cleaning vessels afloat which I have the honour of submitting to you this evening, consists of what may be shortly described as a travelling lever, fixed in a movable frame. The working model before you is precisely the same as the actual instrument, only it is made to a scale of one inch to a foot, or one twelfth of the actual size. The frame is a wooden sledge held *close to* the side of the ship by two guides, upon which it travels as upon a railway, down to the keel and back. It is wrought vertically over all the ship, except upon the quarter, where it should be angled towards the stern, to allow it to go into the 'run' of the ship.

"The line A, A, A, fig. 33. is an outline of the right side of

Fig. 33.



the sledge, the left side being removed to show the interior. B is an upright fixed to the crossbar C, by the ring bolt D. To this fixed base the other two sides of a triangle, E, E, are attached, but jointed and movable, while the lower side of the triangle G passes through double sheaves, beyond the base, ending in an eye for the attachment of the scraper-rope at H. Upon the apex of this triangle, at I, the scraper-blade is fixed, being set at right angles with the shaft, and the long ears at K being at right angles with the edge of the blade.

"As is shown by the dotted lines L, M, when the rope H is hauled upon, the scraper leaves its position at K, and descends to L, where, being beneath the level of the frame, it comes hard in contact with the plates of the ship.

"The lever being still further hauled upon at the fulcrum at O, its longest end pushes forward the bar B, making the machine travel forward on the lines P, which pass through the double sheaves at Q, Q, while the scraper-blade at L continues its course er the ship's plates, sweeping every thing before it.

"By constructing the long ears of the blade at right angles with the edge, they perform the threefold office of keeping the blade within the frame while passing over a hollow at the bow, or the quarter where the blade requires to descend, as is seen at M. They also form an inclined plane for leading the edges over the landings of the plates, so that it is not impeded in its vertical course from the keel upward to the bulwarks. They also prevent the edge of the scraper from going too deep and injuring the paint on the plates, as the edge can never go deeper than the parallel of these inclined planes.

"The ropes S and T are used, the former for lowering down the machine and adjusting it; the latter, as will be seen on the model, is for hauling the machine down to the keel against the natural flotation of the frame.

"As to the power of scrape which the machine possesses, it can be regulated to almost any amount consistent with the strength of the materials of which it is made. By keeping a gentle strain upon the back rope at T the machine will be harder to push along at B, and the power of scrape at L or M will be proportionately increased; or by slacking the rope at T, and also throwing the guide-ropes slack P, P, the machine will be relieved from the pressure against the sides of the ship, and will be consequently easier pushed along at Q; and the scrape on the ship at L or M will be lightened in proportion as these ropes are slackened.

"The other wooden frames or fenders which stand at the keel, the bilge, and against the topgallant rails of the ship, are merely for the purpose of holding the ropes that guide the machine and for carrying the running tackle through double sheaves, and so preventing the friction and abrasion of the ropes against the plates.

"Such is a brief outline of the mechanism of this instrument. It is exceedingly simple in its construction, and easily managed in its working. It is moved fore and aft the ship by fleet lines attached to the fender at the keel. It is thus perfectly under command, and can be sent down to any part of the ship's bottom; and if it is at any time desirable merely to try the condition of the plates, it is only necessary to attach a bag of thin cloth, or small mesh net, to the instrument at the part from I to

Q, and it will bring to the surface whatever it takes from the bottom, so that you may always know whether you are taking anything off, or whether there is anything to take off.

"From the glance that we took at the natural history of the barnacle we saw that they only inhabit the shallow waters. If, therefore, a vessel be gone over with this scraper immediately before leaving a foreign port, and perhaps get into another going over, while waiting for wind in the tropics, she will come home here comparatively clean, nearly as clean as when she went out. If so, then the object so much desired will be gained. Iron ships will acquire that ascendency in point of speed which the material of their construction ought to confer upon them, while the expense of keeping them clean will be less than the putting of copper on a vessel of wood, and thus it is hoped another step will be gained in the great march of industrial progress.

102. *Iron and Iron-plated Ships.*—"The Duke of Somerset," says a writer in the "Steam Shipping Journal," "First Lord of the Admiralty, lately presided at a meeting of the Society of Arts, at which a paper by Wm. Fairbairn, LL.D., F.R.S., was read, 'On the Application of Iron to the purposes of Naval Construction.' The subject was one of great public importance. Even since that meeting three iron steamers have been wrecked upon our coasts, catastrophes which have been attended with fatal sacrifice of life, and would seem to imply either that our knowledge in that branch is still very imperfect, or that it has not been applied with sufficient care to our sea-going ships.

"So far as the *Warrior*, and the other specimens of war ships, enable us to judge, the armour is altogether extraneous, and is merely intended for defence, without being in any way wrought into the fabric, so as to be conducive to the durability of the structure. Until this point is decided, ships of war cannot be built on scientific principles, and the consequences of the defect may possibly remain practically undiscovered until revealed by the terrible experiment of war. The question between iron and wood as the material for their construction still remains also unsettled. If wood is ultimately to be preferred, and we must have armour plates, all that can be done is to hang the plates on the sides as a protection; if, on the other hand, the entire structure is to be of iron, the armour plating ought then to form part of the ship. The same fallacious confusion would seem to have prevailed as to the construction of targets, of which we have heard so much, and on which such sums of money have been expended. If, in the formation of a target, our rulers merely wanted a body capable of resisting shot, the matter was simple. All that was required was a something as like an anvil as possibly could be—a lump of iron of the best texture—for such an anvil of proper size will assuredly resist shot. The targets, however, which have hitherto been subjected to trials were generally various combinations of iron and wood, having a two-fold object; but they left the problem as yet unsolved, how such enormous dead weights were to be introduced so as to form component parts of the frame, and this point must be settled before we can boast of having really built an iron ship of war.

"The application of iron to the formation of floating bodies is one of the many great improvements in arts and manufactures which this country has been destined to witness. Rolled plates were first employed in the construction of steam boilers, but we have evidence that they were adopted in the formation of iron canal boats, about the year 1812 in Staffordshire. There would then seem to have been an interregnum of progress for a period of ten years, when, in 1822, we find that the Horseley Company built the *Aaron Manby* of iron. The frame was sent to London in sections, and, being reconstructed, was navigated to Havre and Paris by the late Admiral Sir Charles Napier. It might have been expected that comparative success in this instance would have stimulated exertions in the same direction, but innovations of magnitude required time to bring them to maturity. Another period of rest ensued, when, in 1829, Mr. Houston, near Paisley, ascertained that passengers might be conveyed in a light iron boat drawn by two horses on a canal at the rate of nine or ten miles an hour. At this very time a new and unexpected era in the history of transit burst unexpectedly upon the world in the experimental tests and competitive trials of locomotive engines at Rainhill, preparatory to the opening of the Liverpool and Manchester Railway. Alarm immediately seized all the canal proprietors, and the speed so attained by the iron boats furnished the only gleam of hope that they would be able to compete with any prospect of success against the powerful antagonism of the locomotive and the rail—an anticipation which proved signally fallacious. The appliance of steam to transit on land, then in its infancy, was followed by the introduction of iron vessels, also propelled by steam, on the Forth and Clyde Canal; and shortly afterwards the *Alburka*, a small iron boat with a shallow draught of water, built by Messrs. Laird, was sent to Africa for the exploration of the Niger. We can scarcely imagine a more striking contrast than these small beginnings present when compared with the enormous increase and present extensive use of iron as a material for shipbuilding, in its application not only in this country, but also in every Maritime State of the globe.

"Ductility and tenacity are the properties most highly valuable in iron, and constitute the true measures of its strength and practical utility. On no account should any plate be permitted to enter into the construction of any sea-going ship that is not capable of enduring a tensile strain of 20 to 22 tons to the square inch, although, unfortunately, many plates are employed which are considerably beneath that mark. Boats on canals and rivers may possibly venture on an inferior standard of quality, but there is no economy in the use of bad material, which is neither safe nor durable. The experience obtained during the erection of the Conway and Britannia tubular iron bridges—the strains in a ship and in a monster girder being nearly analogous—has led to great improvements in the mode of uniting the joints of the plates which constitute longitudinal sheathing. The riveting machine has been invented for the process. As rivets are inserted hot and compressed by the machine, the joints are brought closer together by contraction as the rivet cools. The relative strength of the joints of plates, as compared with the plates themselves, is an important element in the construction of a secure iron ship, as the action of a vessel pitching at sea is a continued series of alternate strains. A vessel of war covered with armour plates, or a trading ship with a full cargo, when meeting a gale, plunges heavily in a rough sea. The waves meet her with violent shocks, which not only tend to slacken her speed, but cause her to tremble or vibrate on the crest of every opposing wave. This is more apparent in iron than in wooden structures. By extending the weight in the direction of the bow or stern the strains are increased; and, as a general rule, the weight ought to be concentrated as nearly as possible towards the centre of the ship. As the centre is subjected to great tensile strain, the only safeguard is increased strength at midships by strong longitudinal keelsons and double bottoms, with a sufficient number of water-tight bulkheads, dividing the ship into several distinct compartments. The engines being also placed in the centre, materially increase the weight in that quarter; and to central weakness may be traced the melancholy fate of several ocean steamers. A striking illustration of the disasters attendant on defective construction has very recently occurred in the loss of the mail steamship *Jura*, by striking while at full speed upon the Crosby Spit, a narrow sandbank at the entrance of the Mersey. The fore part of her keel became fixed on the bank, the stern hanging in deeper water, and she parted in the centre, entirely from the want of a judicious application of iron binders on each side of the upper deck, so placed as to balance the area of the hull, and resist the tension which literally tore her to pieces. Time is an element in the endurance of structures when subjected to severe strains, affecting their ultimate power, although it is difficult to determine what is the correct measure of safety—whether one-fifth or one-fourth the breaking weight; but we have ample data to be assured that every disturbance, however minute, in the molecular formation of bodies, finally tends to their destruction, and it is only a question of time when the rupture is to ensue. We may, however, assume that a ship as well as a beam is practically secure for a series of years when the strains do not exceed five tons to the square inch upon the wrought iron plates of which it is composed. In determining the distribution of the material in the different parts of the vessel, so as to establish, as nearly as possible, perfect uniformity of strength, it is essential that the resistances should be proportioned to the strains, so as to maintain the balance of opposing forces. This branch of the subject would properly fall under the supervision of that section of the Board of Trade which is supposed to be devoted to Navigation, but it would seem to have been but little studied; and after so many wrecks of iron steamers, it is not surprising that that department of the Administration does not stand high in *public estimation*.

"The present class of war steamers are nearly double the length of former sailing vessels, but with a view to increased speed, their depths are much less in proportion, so as to render their power of resistance considerably less than would be the case had the old principle of construction been observed. Contrast a first-rate built in the last century with the *Warrior*, and we have the length of the former, 260 feet; breadth, 60 feet 1 inch; and the depth, 53 feet 10 inches; while the length of the latter is 380 feet; breadth, 58 feet 4 inches; and depth, 42 feet. When the comparative weight is distributed, the *Warrior* will be found to have but little more than half the strength of the *Victory*. This is a matter for grave reflection.

"It has long been settled that a ship was a girder in principle; but another great question of the day to be determined is, whether our ships for the Royal Navy are in future to be constructed of wood or of iron, or after the example of the targets, of both—that is, of iron backed by wood. The commercial advantages of iron in the construction of ocean ships would seem to be acknowledged by the universal testimony of the mercantile community; but fouling has been hitherto found to be one of the great difficulties with respect to iron vessels of war. Sheathing iron ships with timber, and then covering the sheathing with copper, has failed. The galvanic action cannot be counteracted; it proceeds between the iron, the copper, and the salt water, notwithstanding strips of intervening material, and in despite of every device which has been as yet suggested by science. Asphalte has been tried, and a coating of brickwork covered with asphalte, but it was found that the brickwork only contributed objectionable weight. There might not be immediate metallic action, but the water was in itself a sufficient medium to carry on the galvanic effect, which accumulated at the point of contact in the iron plates. The mischief was less to be apprehended in the lighter construction required for mercantile purposes; but it was a formidable, and as yet irremediable, defect in iron ships of war. The possible effect of modern shells on wood sheathing has also to be considered. According to the opinion expressed by Captain Selwyn, R.N., such sheathing would probably be stripped off before the ship had been ten minutes in action, or would be set on fire; and even if the wood were rendered partially incombustible, which no doubt could be effected, the smoke from the smouldering timber would be likely to render the ship untenable. The Admiralty was certainly placed in a position of difficulty, being suddenly called on from all quarters, in consequence of the ambitious efforts at superiority of the French Marine, to provide war ships of the best iron and projectiles of the best steel. To these sources of embarrassment was to be added the perhaps still greater difficulty of finding and applying true mechanical tests of the resisting power of the former, and of the destructive force of the latter. The discussion at the Society of Arts was closed by this important and startling admission from Dr. Fairbairn—who has always been a strenuous advocate of iron in the structure of our war ships, and was also a prominent member of the Commission of Inquiry on the subject of iron—that if we were to have 300 or 400 pounder guns, it was a question with him, being limited to a certain thickness and weight of plates, whether it would not be better to be without armour plates altogether and allow the shots to go through. If vessels were to be covered, according to the most modern plan, from stem to stern, and five feet below the water line, they could not carry plates capable of resisting guns of such large calibre; and with such a description of naval ordnance, his opinion was that we should have a more secure and better navy without armour plates than with them. This announcement, coming from an authority generally considered so competent, may excite surprise, and is certainly not a very encouraging prospect for the nation, after the anticipations we have formed and the expenditure we have witnessed. We may perhaps find ourselves reduced to the position of those knights of old we read of in ancient chronicles, who, encompassed with armour plates, and encumbered by their weight, when unhorsed lay helpless on the ground unable to rise, and were easily dispatched by the dirks of the lighter equipped men at arms. It would be humiliating, but is by no means an impossible consummation, that our splendid ships of war, whose iron plates increase their displacement, sink the line of flotation, and impede the speed, should be equally at the mercy of light wooden steamships, capable of the highest motive velocity, and armed with artillery of the largest size."—*Practical Mechanics' Journal.*

103. At the meeting in 1865 of the "Institution of Naval Architects," various papers of importance were read. Of these, abstracts were given in the "Civil Engineer and Architect's Journal," of which we here take the following:—

(*a*.) *On the Composite System of Shipbuilding, as applied to Vessels of War.* By Alexander M'Laine, Associate. "After remarking that vessels constructed solely of wood are not likely again to be built for the purposes of war, and that it still remains necessary to use wood, in order to secure the protection of copper or yellow metal sheathing, Mr. M'Laine further observes, that the strength of an iron vessel is in her skin, and not in her framing; hence the solution of the problem is not to be sought in an iron frame with a wooden sheathing. Moreover, he attributes the rapid destruction of iron, exposed even indirectly to the influence of copper sheathing, chiefly to the voltaic effect of the galvanic battery, produced by the infiltration or leakage of water impregnated with copper into the space between the iron skin or frames and the outside planking. He thence draws the conclusion, that if the space last mentioned could be kept perfectly clean and dry, without allowing the foul leakage to come in contact with the iron, the mischief would be in a great measure avoided. The difficulties incident to keeping a vessel perfectly tight are very serious, and the author proposed, in preference, to keep the leakage free from the iron of the structure by building vessels with keel, stem, sternpost, frame and outer planking nearly the same as those of an ordinary wooden vessel; but instead of the ceiling or inside planking being composed of wood, it is to be constructed of iron, united round at the bottom and heels of the vessel, and made [illegible]ughly water-tight, forming a complete inner skin of iron, [illegible] beams, stringers, keelsons, bulkheads, platforms, &c., also of [illegible] The greater part of the wooden frame to be merely of [illegible]ons sufficient for bolting the wooden planking to, and to [illegible]ted between iron frames riveted all round the outside of [illegible] ceiling. The wooden frames to be fastened to the iron [illegible] by galvanized iron fore-and-aft bolts, either screwed or [illegible] The wooden floorings to be made deep in the throat and [illegible] with plates on each side, riveted to the angle-iron [illegible]or iron floors to be fitted inside the iron ceiling to supply the requisite transverse strength. The apron, inner post, and dead wood to be inserted between, and bolted to large angle-irons, riveted on the iron ceiling. The outer planking within the influence of the copper sheathing to be fastened to the wooden frames with screw treenails, or with yellow metal bolts. The top timbers of the frame to be, by preference, composed of teak, and in the wake of the armour plating, the spaces between the frames to be filled in solid with teak, or with any other suitable material; the iron ceiling to be also increased in thickness, and additional webframes to be introduced at intervals to resist shot and strengthen the vessel. Owing to the iron ceiling in the system of construction described being perfectly tight, no foreign matters could get into the spaces between the frames to decompose in the bilge water, and generate gases injurious to animal life and productive of decay in timber exposed to their influence. These frame spaces, which would be kept constantly dry by frequent pumping, would therefore be eminently eligible for the introduction of a thorough system of ventilation through the vessel by driving a current of fresh air, taken from above, through the box keelson, thence through apertures in the bottom of the keelson opening into each space between the floors, then up through the spaces between the frames, and out into the 'tween decks, through apertures in the iron ceiling, grated over and fitted with adjustable covers, capable of regulating the amount of the ventilation. The ventilation described would be of immense importance in furnishing the crew, in any weather, with a regular and easily controlled supply of fresh air, and would also, at a small expense, immensely increase the durability of the vessel, and a three horse engine would probably supply power sufficient for the ventilation of a ship of 3000 tons register."

(*b.*) *On the Construction and Sheathing of Iron Ships.* By T. B. Daft, C.E.—"After pointing out the practical failure of paints and other compositions to preserve iron vessels from fouling, or even to remain in close adherence to the surface, Mr. Daft brought forward a proposal to re-arrange the plating of iron vessels in such a way as to produce a fair flush surface, so as to afford a good foundation for sheathing. This he would obtain by leaving a space or groove between one plate and another in the *skin of the ship;* these grooves to be 'caulked' or filled in with teak or other suitable material, pared off flush. Butt-straps would thus be required longitudinally as well as vertically; but Mr. Daft considered the method to be more advantageous as well as stronger than the ordinary plan of butts and laps, besides conducing to speed. Without sheathing he considered such a surface preferable for the retention of paint or composition. But he preferred to sheathe, and with zinc. He stated that this metal not only preserved the iron galvanically, but that the slight exfoliation of the zinc itself, due to the voltaic action of the iron in contact with it, caused it to exceed both copper and yellow metal in cleanliness. He produced a specimen which had been immersed for twenty-eight weeks in the sea off Southend. The bare iron was coated 6 or 8 inches thick with weed and barnacles. The zinc was clean, and had only lost a twenty-fourth part of its original thickness. A specimen of a similar experiment had been deposited in the Naval Gallery of the South Kensington Museum."

(*c.*) *On a Proposed Method of Combining Wood and Iron in Composite Ships.* By Michael Scott, C.E.—"The author stated that his method combined the strength of the iron ship with the capability of being coppered afforded by the wooden ship. The leading features of the plan were as follows:—

"First, the iron structure.—This with the following exceptions was described generally as being similar to an ordinary iron ship. The exceptions were—1st. The frames formed of T iron, stronger and spaced further apart. 2d. Amidships and extending to the furthest forward and the furthest aft bulkheads, the vessel only plated to the lower turn of the bilge, the ends only being plated complete. 3d. The joints of the plating all butt-joints; the plates close to the frames; liners dispensed with, and the butt strips outside. 4th. Extending from the upper edge of the bottom plating to the lower edge of the sheer strake, a series of diagonals formed of flat bar-iron riveted to the plates at top and bottom to the frames, and to each other wherever they cross; a framework is thus obtained having the strength of an iron ship, but it is only a skeleton which requires flesh and skin in order to become a complete body.

"The next step, therefore, is to fill the spaces between the frames solid with two thicknesses of wood, the outer thickness composed of timbers running parallel with the frames, and the inner thickness of timbers running at right angles to the frames. The outer thickness would be creosoted and caulked. The inner thickness may, or may not, be similarly treated. And both thicknesses would be fastened to the diagonals with iron bolts passing through all. If preferred, both thicknesses of wood might be placed vertically, the one covering the seams of the other. In order to bring the surface of the wood outside, flush with the surface of the diagonals, the spaces formed by these would be filled with thin boards in two thicknesses, one set of boards filling between the inner diagonals, and another set between the outer diagonals. Over all would come the outside planking like that of an ordinary wooden vessel. It would be fastened by treenails or by copper bolts passing between the diagonals and frames, and through the several thicknesses of wood. Mr. Scott then proceeded to describe the detail of the construction of the bow and stern. The author considered it an important feature of his method that, whilst bolts are employed to keep the wood in place, the strain to which the vessel is exposed are not taken by these bolts. The internal capacity is as great in proportion to their displacement as in iron vessels, and greater than in wooden vessels."

(*d.*) *On some Recent Experiences in Marine Engineering.* By Robert Murray, C.E., I.N.A.—"This paper was intended to give a record of Mr. Murray's experience on certain controverted points of marine engineering, namely, surface condensation, combined cylinder engines, superheating, the relative advantages of screws as compared with paddles, and the durability of shafts.

Surface Condensers.—It was found that the water, while free from salt, was apt to become very foul, the result being that the tubes of the condenser got blocked up, while the boiler was exposed to even more rapid deterioration than under the influence of hot brine. There was a set off, but not an adequate one, in a diminished consumption of coal. Mr. Murray thought that, on the whole, there was little or no saving in their use at present.

Combined Cylinder Engines.—By a comparison of the performance of the Poonah, Delhi, and other vessels of the Peninsular and Oriental Company, with the Saxon and Roman of the Cape Mail Company, Mr. Murray was led to the conclusion that there was no such advantage over the single cylinder as would compensate for the increased weight and complexity of the combination.

Superheating.—Mr. Murray stated that it might now be considered as certain that this process is desirable for all vessels which make long voyages, and which use expansion in the cylinders to any considerable extent. In the smaller class of coasting and river steamers, where the trip was short, and the engines not worked so expansively, superheating did not answer so well. In any case the temperature of the steam at the superheater should be limited to 320° or 350° at the utmost.

Screw v. Paddle, for Ocean Steaming.—Mr. Murray considered that this question was by no means in a settled state, and discussed in detail the circumstances under which either method had advantages over the other. He remarked that screw vessels were often placed under circumstances disadvantageous for comparison by being underpowered.

Shafts.—Mr. Murray stated it as an established rule, that shafts, whether paddle or screw, will not last beyond a limited time, failing sometimes after five years' work, in other cases lasting ten or twelve years, but always being deteriorated by use. After discussing the cause and manner of this deterioration, he stated circumstances which led him to form a favourable opinion of the recent introduction of steel instead of iron for the shafts both of paddle and screw engines."

(*e.*) *On the Construction of Armour-clad Ships of War.* By Rear-Admiral Sir Edward Belcher, C.B.—"Sir Edward Belcher commenced by remarking that no reasonable thickness of iron plate, as applied at present, or proposed to be applied, for the coating of our iron-clads could be expected to withstand the heavy ordnance which it is contemplated to use for service afloat, and that our ships of war were at present so over-pressed with armour that they were virtually inefficient as rapid, handy, and active cruisers; his attention had therefore been directed to a different mode of presenting the iron works, of rendering the hull less penetrable than it is at present, and of diminishing the effect where penetration is effected, as regards splinters. Eventually, if the vessel were constructed, as regards her ribs and filling between them, on the plan proposed by the author, then she could be planked and sheathed with copper similar to our old timber-built vessels; free, moreover, from the liability of water coming at all in contact with the iron. By the practice at present pursued, the heavy and unmanageable iron plates, varying in weight from 3 to 4 tons, depended for their security of attachment to the slender framework upon through-bolts, screws, and other adaptations, all proved more or less insecure; and as yet, none of these vessels had been subjected to the reality of an action, the much more dangerous trial of grounding, or the continued concussion of severe gales loosening the fastening within as well as without—for the treatment of the targets at Shoeburyness was not to be compared with active warfare. But even there it had been proved that no thickness of metal yet presented for test had withstood the heaviest gun we even now possessed. But it was not the penetration which was most to be feared; it was the effect of the shot or shell after penetration, the yet untried difficulty of remedying the disaster resulting from one well-directed shot, and the insufficiency of the hull itself to carry the guns with that amount of armour-plating which was intended to protect them.

"At the late meeting of the British Association at Bath, Sir Edward Belcher had given an outline of what he had now more fully matured. He began by assuming that as our ships were only baskets in regard to resistance to these heavy guns, we required in the first instance, irrespective of the ordnance, such shells or carcases of ships as would withstand a good fight, and be to a certain degree fit to renew action with vessels similar in force to our present armoured vessels, yet to possess greater comparative invulnerability, or, in plain terms, to possess greater adaptation for defence, and facility for remedying damages, than any we now possessed. A ship of this description demanded merely such protection up to her deepest line of flotation, or ordinary rolling angles, as would shield her machinery effectually, and, under ordinary action, be free from liability to sink within a rational period demanded to repair defects or efficiently close any specific perforations. With a hull so prepared, and decks rendered bomb-proof as regards oblique or glancing shot, the fighting batteries for guns and their crews would become but a secondary *consideration*, as most seamen who have seriously considered the question would probably prefer lighter bulwarks through which shot and shell could pass freely, than be subject to the frightful effect of being boxed up and mutilated by the very splinters of the plates provided for their protection.

"The admiral advocated building the ship herself of such strength by the very process of construction, by placing in her framework, in a peculiar manner, such a proportion of iron that iron plating should be needless, and that it would be possible to sheathe and copper as of old, and to repair damages during action with the same facility as our forefathers did. In fact, he proposed to make his frame so far shot-proof that it would not only bear comparison with the heaviest iron-clad, but would come out of action always in a condition to renew it, instead of running home to her parents here to wipe off her tears resulting from lameness. He then passed to the explanation of the mode by which he proposed to attain his object, and to compare the build of the present Warrior class and her weight of iron. Her ribs are 2 feet asunder, and the thickness to carry the plates is but ⅝ths. She is filled in with teak, which does not however enter into her strength. Each cubic yard, as before stated, weighs 3,123 lb. Assume 8 inches to be the diameter of the shot or shell to be used, the author gave 7 inches space between the ribs, which are to be 18 inches wide and 2 inches in thickness, cold short or case hardened on the exterior surfaces. His proposition was, to fill in with a peculiar substance, termed at present 'zopissa board,' possessing the same specific gravity as teak—viz., 48—but of fourfold resistance, incombustible, protecting iron, resisting water, and, finally, an absolute non-conductor of galvanic electricity. Now, as the specific gravity is the same as oak and teak, teak might be assumed for the present as the filling and backing. Therefore, taking into consideration the necessity for protecting the iron from external influence, he would first bring on 2 inches of this prepared paper (if wood be preferred after due experiment, or the zopissa board, to supersede it), and over it 4 inches of teak. Within, he would bring on 2 thicknesses of 3-inch paper board to resist splinters if shot penetrated. Then followed a tabular comparison between the construction recommended by the author and that of the Warrior, and a detailed discussion of the probable effect of shot upon the two vessels. The zopissa paper board was stated to be the invention, or rather discovery, of Colonel Szerelmey, formerly on the staff of the Austrian army. It was not a supporter of combustion; it was capable of being used in mass without waste,—indeed similar to a fusible metal. It was free from any particle of moisture; and whereas any ordinary paper would corrode iron, it, on the contrary, adhered to and formed over it a covering impervious to water. If our iron-plated ships had this substance interposed between the plates and ribs, and used as filling, the vessel would be safe, even if her armour-plating fell away. It was an absolute non-conductor of heat, cold, or electricity, and the time was, perhaps, not far distant when its use in covering boilers, steam tubes, funnels, &c., would become very general.

"Sir Edward Belcher concluded with the following remarks:—I had intended, as I first stated, to have simply placed before the institution the *quasi* invulnerable and unsinkable shell of my corvette, for I would leave the protection of the men to those who think more about such matters. But I wished to add one more effort to bring all the guns to perform their duty. It is immaterial to me if you give each gun its turret—on the deck, not Coles's revolving—or bring round your connecting bulwarks for them, but I think my hearers will not fail to understand that I have so transposed Mr. Reed's rectangular box into a lozenge, that I lose no strength in whatever direction I may be assailed. I am able to show five guns ahead, astern, or abeam, by the slightest possible deviation from the course. That subject is of too much importance for a short observation. As to offence of the vessel ahead or astern, she is adapted to go over or under my adversary, and presents a sensible tool for an intelligent workman; such a tool precisely as we use in the cutting of iron. I remove my length of keel, and thus facilitate turning, on the principle of the famed 'mugian' (Bermudian), which has only half her deck length on her keel, and the rake of stem and sternpost at opposite angles, I propose to facilitate turning. These are secondary matters not involved in my programme. I may observe that the use of paper-board would deaden concussion considerably. I now turn to my unsinkability. It will be seen that I have added a vertical barrier to support my coal resistance backing the new construction. That a very small portion of my vessel, merely the segment of 45 degrees of her rounding, demands protection. That the coal-bunkers representing coal at 72 pounds the cubic foot cannot come into the category of bilging a compartment, to admit salt water at 64·4 the cubic foot. That the bunkers are so arranged as to keep the coal pressed home to the sides and conduct the water to the bilge. That the vertical supports resting on the floor-ends sustain the vessel completely if she grounds; and, finally, if she grounds and makes a hole, these spaces under the engine-room, fore and aft, capable of being made air-tight, will, by the common sense operation of condensing air, drive out any water that may enter, as I shall have occasion to illustrate by experiment on reading my other paper. I have already proved, as proposed by me in 1826 in Bermuda, and illustrated lately before a chairman of the London Docks, that the air in the lungs of a man can raise a model lift for a vessel, representing about 500 pounds, in about 20 minutes. That depends simply on the *modus operandi;* and I believe that with a certain amount of scientific disposition in the internal fittings of our ships, most of the bugbears of sinking could be easily overcome."

104. *On Turret Ships.*—From an article under this title in the "Engineer," Sept. 22, 1865, we take the following:—"One great objection to the central battery system lies in the difficulty met with in training and working heavy guns. This difficulty Captain Coles overcomes very fairly by the aid of the turntable. It is possibly not too much to say that no other scheme answers the intended purpose better. The defect of the turret system, on the other hand, lies in the difficulty of manœuvring, mounting, and putting in motion an immensely heavy armour-plated structure, carried so high as almost to constitute that worst of all cargoes, a moveable deck load. It is not necessary that we should enter upon the consideration of any other of the multifarious problems connected with the subject of the comparative merits of the rival systems. It is probable that were the question of working heavy guns once set at rest by the use of a simple mechanism, nearly, if not quite, unexceptional in its mode of action, the battery system would have greatly the advantage of the turret. Good results might, we think, be obtained by adopting a fixed cylindrical or oval turret, armour-plated, and

answering in most respects to the Reed battery, within which one or two excessively heavy guns should be worked on an independent revolving turntable. The turret should, of course, be provided with two, or possibly three port-holes on each side; and by simple mechanism the gun would be trained to fire from any one of these as might be found expedient; the others, of course, being closed for the time by heavy port shutters of armour plate. It is unnecessary to go into details here. Engineers will perceive that the working of these shutters, even if made of 8 in. iron, would entail no insuperable difficulties. In point of fact, means might be adopted for excluding shot, which, acting the part of a shutter, would yet be totally distinct from any scheme yet employed to the same end to which the name could be applied with strict propriety. The range of aim would not be limited, as the gun could be trained so as to fire right and left through each port-hole at angles, which would include a field far more extensive than that available with any broadside port now in use. The advantage possessed by such a system over that of the ordinary turret would lie in the fact that the great mass of the turret being a fixture it could be built in with, and indeed form part of, the ship; while the rotating table and its mechanism would be comparatively light and easily worked, and would receive the most absolute protection which armour-plating can bestow. The advantage over the central battery would principally reside in the facility for working heavy guns, and of obtaining a very wide range of fire without moving the ship. The circular form of battery, too, is exceedingly strong, and something might be gained, doubtless, in the saving of weight consequent upon its use as compared with the square 'box' with armoured bulk-heads athwart-ships. Whatever may be said upon the subject, it is beyond question that a better and more permanent job may be made of a fixed than of a moveable turret, and as the great object subserved after all by the power of rotation is the working of the gun within the turret, it is worth considering whether equally good results may not be obtained by causing the guns to revolve without their armour. The main argument, indeed, urged in favour of imparting rotation to the turret, is based altogether on an assumed difficulty in providing stoppers for *ports not* occupied by guns. As to this point we are disposed to think that a better expedient can be adopted than one entailing the necessity of putting sixty or seventy tons of iron, &c., in motion every time a gun requires to be trained through a few inches."

DIVISION TENTH.

TELEGRAPHIC CABLES.

105. *The Atlantic Cable.*—The great, and, we may say, the unfortunate feature of the year in this department of practical engineering, was the failure of the attempt to lay the Atlantic cable. This failure has brought out, as may be easily conceived it was likely to bring out, a large amount of criticism and remark, characterised by remarkable diversity of opinion. To give all the papers which have appeared on the subject, or indeed but a brief abstract of them, would take up a very large portion of our present volume; we are compelled, therefore, in view of the large amount of material at command, to take but here and there such a portion of it as will convey a fair notion as to what has been said pro and con. The "Engineer" has an article under date August 18, 1865, from which we take the following:—

"The news which has at last come in from the Atlantic is, on the whole, better than that which the public generally anticipated. The expedition returns, it is true, after having failed to carry out the undertaking for which it was designed, but hopes of future success are strengthened rather than diminished by the nature of the obstacles which have been encountered. The cable has not been lost altogether, and there is reason to hope that it may ultimately be recovered. The difficulties which have proved so fatal to the present attempt, may, on another occasion, be overcome or avoided, and are not fatal to the principle of ocean telegraphy. The accidents, indeed, which are said to have caused the loss of insulation—which three separate times rendered it necessary to pick up the cable—are not only exceptional in their nature, but are so extraordinary, and unlikely to have occurred, that it is only a strong belief in the integrity of the Construction Company's engineers which renders it possible to accept their explanation of what has taken place. According to the telegram received from Crookhaven, the original cause of the defeat which the Great Eastern has sustained was a small fragment of wire, nipped from the end of one of the outer strands of the cable during the formation of a splice. . . .

"Meanwhile, several things have been ascertained—several feats have been accomplished—which promise well for the next attempt. Some of the facts reported are unfavourable, it is true, but the whole story, as given in the Company's telegram, is encouraging. Three times did the Great Eastern grapple successfully for the lost end, though the water was 2,000 fathoms in depth. The end was not on any one of these occasions brought to the surface, but it was found and laid hold of. When we consider the depth at which this was done, the friction of the grappling-rope in the water, which added to the difficulty of detecting the strain when the hook touched the cable, and the probability of passing over the object sought without obtaining it, we must grant that the partial success of the efforts which were made is sufficiently surprising. Considering that these attempts were successful in what seemed the most difficult part of the work, it is, indeed, also surprising in a different way, that each time they ultimately failed by the breaking of the grappling rope. It is probable that the iron wire buoy rope, which was made in contemplation of different accidents from those which actually took place, was used with the grapnel; and this was made, if we remember rightly, of nine wires—three strands of three wires each—similar to those used for the outer covering of the telegraph cable. Its breaking strain was probably not less than ten tons, and it ought, one would have thought, to have raised the cable to the surface after the grapnel had once caught. Yet in the four attempts made it parted three times, and only came up safe on the other occasion because it had not fastened on the cable. It is tolerably clear that the slack of the cable came up safely, but that the bight was not large enough to reach the ship. As soon as the cable tautened the strain became too much for the grapnel rope. Now it is very easy to make a rope to bear this strain, but an alarming thought suggests itself—Will the cable *bear it?* *What has* been done shows that a rope is not lost be cause it is allowed to fall to the bottom of the Atlantic Ocean. That is a great discovery, and does much credit to the engineers, who had no experience to guide them in making it; for we believe that the greatest depth at which grappling had been attempted successfully before the present expedition sailed, was 600 fathoms. Of what use is it, however, if the tension on a cable in raising it through 2,000 fathoms should prove too much for it to bear? A steel wire grapnel rope could easily be made, which would stand a much greater strain than would be put upon it by the weight of the cable; but it is not by any means certain that it would bring up the electric cable, with a breaking strain very little greater than that of the rope which has been used unsuccessfully. Of course there was a greater strain on this rope during the grappling operations than on the cable itself; but, on the other hand, the strain would increase very greatly as the cable neared the surface, and the length raised from the bottom extended. This consideration may naturally give rise to some anxiety with reference to the success of the next attempt.

"Another source of apprehension may be drawn from the accident which first led to the necessity of grappling—the fracture of the cable at the bows of the ship. The hauling-in apparatus has done its work satisfactorily on two occasions, and the accident on the third is not conclusive against it; but for the cable to break on board after it had been fairly recovered from the water is discouraging. . . . .

"There is another point in the management to which the events described direct notice. When the loss of insulation was discovered, electrical tests put the fault six miles from the ship. Surely it is strange that six miles were payed out without a test for insulation having been applied during the whole time. The public was given to understand that currents were flowing through the cable constantly, and that its condition was incessantly watched by the electricians. Now it is revealed that the whole staff were in ignorance of the state of the cable during the best part of an hour, for the Great Eastern must have taken nearly that time in paying out six miles. Considering that Mr. De Sauty refused to allow any verbal message to pass through the cable during the voyage, on the ground that such messages would interfere with the constant vigilance necessary to ensure a good result, the inference that we are bound to draw from the facts before us is not a little astonishing."

In an article in the "Mechanics' Magazine," August 25, 1865, the "past" and the "future" are treated of; we take from this the section on the future.

"To pass at one bound from a retrospective to a prospective view of matters is in this instance admissible, inasmuch as the past and future of the Atlantic telegraph cable are connected by a present which consists now of only a single link; that link being the fact that 1,200 miles of cable lie stretched across the bed of the Atlantic. But its future commences now, nay, it commenced as soon as the 'Great Eastern' had recounted her history; so to that future let us turn. As a starting point, we will take the conclusions which may be legitimately drawn from the foregoing narrative. The perfect adaptability of the 'Great Eastern' for the work of laying down the cable is evidenced by the fact, that in a stiff breeze, when the sea was washing over the 'Terrible,' scarcely any motion was perceptible in the 'Great Eastern,' her greatest roll being 7½ degs., and her greatest pitching 1 to 1¼ deg. The big ship, therefore, by her wonderful steadiness at sea, and from the facilities for steering which her screw and paddle engines afford, is proved to be eminently adapted for cable-laying. But to render her fit for future service she unquestionably requires careful overhauling and repair. Improvements will have to be made in the arrangement of her tanks and coils, whereby she may carry her full complement of boilers, for it can be imagined she must labour under a disadvantage when working *minus* two boilers. Amongst other things requiring attention to the end that she may be made truly serviceable, are certain points of construction which at the present time appear rather weak. The strengthening is proposed by Mr. Fairbairn to be effected by placing additional stringer plates on the upper deck, and probably a short way down the sides, so as to increase the ship's powers of resistance to strain with a heavy cargo on board, such as she had from the Nore to Valentia. This being done, the 'Great Eastern' may with safety be trusted on any sea and in any weather. It may be that the future of this vessel *will become entirely* identified with the pursuits to which she has been so appropriately appointed, and for which she is so admirably fitted.

"With regard to the machinery for laying the cable, nothing that can be said in its favour appears too strong praise; whilst the reverse of this holds with respect to the hauling-in apparatus and tackle. But it must in fairness be said that such a contingency as having to pick up the lost cable from a depth of two miles and a half was never anticipated; hence the failure—the grappling gear was inefficient. The remedy will be to have an engine fitted to the paying-out apparatus, so that in case of need its action can be reversed and the machine used for hauling in. This would enable a fault—if such occurred—to be recovered very soon after it had left the ship, immense time also being saved by avoiding the operation of shifting the cable from stern to head. Machinery will also be fitted in the bows of the vessel for the purpose of fishing up the present cable. All these of course are simple matters of detail, the best methods of arranging which will be determined by the experiences recently gained. The picking-up apparatus, too, will of course be constructed consistently with the duty it has to perform in recovering the cable, which duty has been well ascertained, so that no excuse is left for mechanical failure in this respect. The question had not been practically dealt with before, and so was unprovided for, or we should probably now be recording congratulatory messages carried by the subtle fluid from President Johnson to Queen Victoria.

"The cable itself has all the requisites of strength and the right specific gravity; it never went over the stern at a greater angle than 7 deg., and never showed a greater strain than 14 cwt. upon the dynamometer. Its insulation improved daily as the cable became influenced by the lower temperature of the deep ocean. Its present failure is due principally to one of its own wires having penetrated the gutta-percha core, and this cause has been so far fatal only because it was not anticipated. Every kind of experiment had been previously resorted to, but the wire never before penetrated the core. This, taken in connection with other circumstances, appears to have directed some of the leading minds to the conclusion that the faults were the result of malice, although Captain Anderson inclines to a contrary opinion, believing them to be the result of accident. But whichever way the truth may lie, it certainly follows that such appliances only should be used as would prevent the recurrence of such fatal results. In order to afford additional security, Captain Anderson suggests that the outer protecting wires should be formed of a number of smaller ones, so that no single wire would be sufficiently strong to penetrate the core; or if necessary, the core might be covered with canvas or wire gauze to make it still more secure. The cable is perfect in its insulation; it possesses the right specific gravity, the right strength, and fails only in one respect—that of being capable of wounding itself. But there is enough of experience now to check its suicidal tendencies, or if not to prevent, at any rate to remedy, at once any wound that may be inflicted, whether by itself, or by Mr. Russell's 'cable assassin.'

"In the ordinary course of things, and had there been no let or hindrance on the part of the vessel herself, the 'Great Eastern' would probably be dispatched on the voyage of recovery a few weeks hence, armed with efficient picking-up tackle. But as the necessary repairs will occupy some two months, the expedition could not leave early enough for useful effect. Winter gales would probably drive the ship from her work, and without the sun the locality of the cable could not be discovered. It has therefore been concurrently determined by all interested in the question, that the better plan will be to delay the voyage until May next year. In the meantime a new cable will be manufactured, which will be sent out in the 'Great Eastern' when she goes to recover the other one. This cable will be of the same character as the last, with the exception perhaps of a slight addition to its outer covering, but which will in no way interfere with its specific gravity, or any other condition already proved to be satisfactory. The process of picking up the cable will, doubtless, be on this wise:—The 'Great Eastern' will proceed to within ten miles of the extremity of the cable, so as to keep clear of the grapnels and tackle now resting on it. She will then drag until the grapnel bites, when she will commence hauling in. Another vessel—say the 'Terrible'—will be going through the same operation a mile to the east of the 'Great Eastern.' The latter vessel having obtained a hold will probably break the cable in the lift, and will then proceed eastward on the course of the cable about half a mile astern of the 'Terrible,' where she will again grapple for, and no doubt lay hold of, the cable, which, with the bight thus formed, will be comparatively easy of recovery. The recent deliberations of the boards of the several companies interested in the Atlantic telegraph cable have been distinguished by a spirit of the utmost confidence in the realisation of a great success next year. Not the slightest doubt is entertained as to finding, with the greatest precision, the position of the broken end by solar observation, and of eventually raising and repairing the cable. The animating principle is a determination to perfect the telegraphic communication between England and America, which object we doubt not will ultimately be effected."

The following is from an article, Sept. 1st, 1865, in the "Civil Engineer and Architect's Journal:"—The second attempt to make telegraphic communication between England and America has failed more completely than the first: for that cable, with all its faults, was stretched from shore to shore, and for two days messages were transmitted, though at a slow rate. The experience then gained, the increased knowledge respecting the conducting power of pure copper, the improved mode of insulation, the precautions taken in making the cable, and the greatly superior appliances to prevent accident in laying it, have proved of no avail; and it now lies broken and useless, two miles under water, in the midst of the Atlantic.

"The misfortune is said to have arisen from circumstances that might be guarded against on another trial, and sanguine hopes are entertained that the broken end may be raised and spliced to the remaining portion still on board the Great Eastern, and thus, after all, the great object may be accomplished by the means already at command. We hope it may be so, but we do not see much ground whereon to rest confident expectation. Great care was taken by the conductors of the undertaking to prevent any reporters for the press from being on board to give an independent account of their proceedings; and the diary that has been published, written by Mr. Russell, former special correspondent of the *Times*, is admitted to be the account of a gentleman who is connected with the undertaking. . . . . The gutta-percha being compressible, it is natural to infer that at the bottom of the Atlantic it would be compressed into a smaller compass round the conducting core of copper wire, and that it would consequently be separated from the external wire rope. If that were so—and we are led to suppose it must have been, by the reported improvement in the insulation as the pressure increased—the strength of the cable would be greatly diminished by its separation into parts, and the stretching power of the external wire covering would be increased as compared with that of the core. It is important, therefore, to know what actually was the condition of that portion of the cable on which its strength mainly depended, and of that Mr. Russell says nothing. It is no less important to be made acquainted with the success of the attempt to increase the rapidity of the signals by adopting a plan that appears the reverse of that which a knowledge of the ordinary conditions of the conduction of electricity would seem to dictate. It is a well-established fact that the thicker the conducting wire the less resistance is offered to the transmission of electricity, and it seems most extraordinary, on looking at a section of the Atlantic cable, that the inner core intended to conduct the electricity should be so small. The reason for adopting so diminutive a conducting wire was this: when a wire covered with gutta-percha is immersed in water, and a current of electricity is transmitted, it becomes charged like a Leyden jar. The conducting wire serves as the inner coating of the jar, the gutta-percha acts the same part as the glass, and the water is the outer conducting coat. Such a wire, when of great length, if charged with electricity retains the charge for some time; in the same manner as a Leyden jar retains some portion of electricity after connection has been made between the inner and outer coating. Thus, when an electric signal is sent through a submarine wire, part of the electricity is retained by the gutta-percha, and obstructs the transmission of the succeeding signals, and some time is required before the wire is sufficiently free from electricity to enable it to do so. That was the cause of the slowness with which the messages were transmitted through the first Atlantic cable—the rate of transmission being about two words per minute. To increase the rapidity of transmission, it was proposed *to increase the thickness* of the gutta-percha covering, for as a thick glass jar cannot be readily charged with electricity, it was supposed that the thicker the gutta-percha compared with the size of the conducting core the less would be the degree of retention. That was found to be the case on making experiments with gutta-percha of various thicknesses; hence it was concluded, that by greatly increasing the thickness of the insulator, messages might be transmitted through submarine wires with little obstruction. The name 'induction' was given to the retentive power of the gutta-percha, and by giving it that name great advance was supposed to be made in the knowledge of the subject. The question was unfortunately taken up by mathematicians, who discovered or invented formulæ for determining the proportionate thicknesses of the gutta-percha and the conducting wire best adapted to prevent 'induction.' The view of the subject of submarine telegraphy was thus completely changed. It became a question of charge and discharge instead of conduction, and it was considered that the best means of establishing rapid telegraphic communication was to diminish the conducting wire to the smallest size, and to increase the insulating coating. On that principle the two Atlantic cables were constructed. The strands of conducting copper wires were little thicker than common bell wire, their insulation was carefully provided for, and they were protected from injury by an external covering of wire rope, of which the insulator formed the core. The consideration of the conducting power and strength of the copper wire was entirely sacrificed to that of diminishing induction and increasing the rapidity of transmission; and it is most essential the public should be informed whether that object was attained, for as yet we are in ignorance of the rate of transmission so far as communication was maintained.

"If the stretching power of the conducting strand of wires were not equal to that of the outer wire rope, it would have to bear a strain enough to break it at any moment, and we should like to be correctly informed whether the occasional interruptions to the communication, attributed to 'defective insulation,' were not, in point of fact, due to the rupture of some of the strands of the conducting wire. The necessity for perfect insulation is the one of the bugbears of marine telegraphy. We have seen very correct signals transmitted through entirely unprotected thin wire stretched through 100 yards of water. The thicker the wire the less would have been the quantity of electricity diverted from its course; and it is a problem we would submit to the mathematicians to solve; if any uninsulated copper wire one-sixteenth of an inch in diameter transmits electricity across 100 yards of water, what thickness should such a wire be to transmit signals from Ireland to America? At all events, it would be as profitable a speculation as the consideration of the minimum size of wire for such a purpose.

"Ordinary knowledge of the property of conduction dictates that the principle on which an electric telegraph to America should be constructed, is that of making the conducting wire of the greatest thickness compatible with the flexibility required for laying it down. It was suggested by Mr. Bakewell, in a paper read at the meeting of the British Association, ten years ago, that the conducting wire of an Atlantic telegraph should be essentially self-protective. The only external protection it requires is near the shore, but at great depth in the ocean no external covering is necessary. A telegraph of that kind might be established at comparatively small expense, and it might be stretched across the Atlantic with much less difficulty than an elaborately fabricated cable. It might be covered with a sufficient thickness of gutta-percha to diminish the specific gravity to little more than sea-water, for it is not necessary the wire should rest on the bed of the ocean. A wire rope made of the purest copper, one-quarter of an inch in diameter, well coated with gutta-percha, might, there can be no doubt, be extended to America without much difficulty, and if such a means of communication were formed, the electrical difficulty of transmitting signals through it—if any such difficulty were found to exist—would be soon overcome. At all events, such a plan is more feasible, more in accordance with the known facts of the conduction of electricity, and would be very much less expensive, than the construction of a complicated heavy cable, that can only be laid down in the Atlantic under specially favourable circumstances, and which depends for its action on the principle of charge and discharge, instead of on the conduction of electricity."

DIVISION ELEVENTH.

BUILDING MATERIALS.

106. *Preservation of Stone.*—On this important subject, to which of late great prominence has been given, the "Building News" has the following:—"Public attention will soon be called to the relative success of the competitors for the preservation of the stone of our new palace at Westminster. It is to be regretted that the season of testing should have been allowed to pass without ascertaining the positive merits of a promising process patented by M. De Wylde, who introduced silicate of potash into this country, and who, under the patronage of His late Royal Highness Prince Albert, applied the silicate to many important uses. The inventor applied for leave to enter the list of competitors on the Houses of Parliament, which was denied him, the reason alleged being that his process was one of a class represented by other competitors. This, however, is not the case, as the following facts will show. No application of the silicates has yet been made without the menstrum in which the silica is dissolved proving hurtful to the stone to which it is applied; or if, by the use of two agents—or an agent and reagent—the menstrum is changed into a salt, that is equally hurtful, being set free to crystallise in the stone, and thus break up its texture. We can thus far see the importance of every application being free from any deteriorating constituent itself, or in any way eliminating such constituent during or subsequent to its application. A now old and exploded theory of preserving stone by silicate of lime was in practice as follows:—Silicate of soda and chloride of calcium (lime) were applied in successive coatings. Suppose that a silicate of lime was formed in the stone, there was the soda that the silicate of lime did not want, and the chlorine that it also could not in its new condition find use for, and thus was a chloride of sodium formed, which unquestionably did more harm to the stone than the silicate of lime did good. M. de Wylde obtains his deposit of silicate of alumina free from an excess of alkali, or from any salt by elimination. Silicate of alumina, say of the class of which feldspar is constituted, must have, in order

to its being a silicate, and possessing the qualities of the above-named mineral, a certain proportion of potash; and the importance of this constituent is nowhere more proved than in the fact of granitic rock breaking up after the resistance of the action of time for centuries, by the abstraction of the potash from the feldspar. This alkali gone, the feldspar breaks up, and the whole mass of that hard and durable rock falls to decay. Silicate of alumina, therefore, owes not only its name, but its durability, to a due proportion of potash. This alkali, however, must not be in excess, or damage to the stone, and the deterioration of the deposited substance must evidently be the result. The avoidance of this ever-present stumbling-block has been secured by the use of a very beautiful preparation called allotropic alumina. In its manufacture, a solution of acetate of alumina is exposed to long and gentle heat, by which the acetic acid is gently removed by vaporisation, the water always being kept at the same level. Thus is the alumina left in solution in the water without acid or alkali, a fact the wonderful character and importance of which can only be appreciated by the chemical world.

"Here, however, is the solution of the problem: silicate of potash, soluble, has—we will say—2 parts of potash to 1 of silica; the insoluble modification has, say 1 part potash and 1 part silica. Bearing this in mind, we shall see that if we admit the alumina to appropriate a share of the alkali we take from the soluble silicate the one part of potash necessary to its soluble condition, and bring it at once to the insoluble modification, the whole forming a true silicate of alumina insoluble and devoid of a free salt of any kind. The case may be more plainly seen by contrast with another existing process; indeed, one of those at present under probation at the Houses of Parliament. In the latter process the one part of alumina is dissolved in two parts of potash, and the one part of silica in two parts of potash. The admixture of these certainly results in a solidification of the mineral constituents by the affinity of the silica for the alumina; but seeing that to form these two bases into an insoluble silicate only two parts of potash are required, we would ask red tapeism how it has provided for the exit of the remaining two parts of free alkali from the stone.

"The following is a table, illustrating the old and new systems of applying silicate of alumina :—

New System.

Silicate of Potash.		Silicate of Alumina.
Silica	1	
Potash	2	
Water		
Allotropic Alumina.		
Alumina	1	
Water		

Old System.

Silicate of Potash.		Silicate of alumina with excess of potash.
Silica	1	
Potash	2	
Water		
Aluminate of Potash.		
Alumina	1	
Potash	2	
Water		

107. *Limes, Cements, Mortars, and Concretes.*[*] By Chas. H. Haswell.—"The calcination of marble or any pure limestone produces lime (quicklime). Lime, from its great affinity for moisture and carbonic acid, requires to be preserved from these deteriorating agents by being packed in close vessels.

"*Limestones.*—The pure limestones burn to a white lime, and give the richest limes.

"The finest calcareous minerals are the rhombohedral prisms of calcareous spar, the transparent double-reflecting Iceland spar, and white or statuary marble.

"In order that lime when brought to the condition of a paste for use as a binding medium shall afterwards harden to solidity, it is necessary that other substances exist in a state of intermixture with it; and these substances are found to be silica, alumina, magnesia, iron, manganese, &c.

"The striking and characteristic property of hardening under water, or when excluded from the air, conferred upon a paste of lime by these foreign substances, when their aggregate amount

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[*] Collected from the observations and experiments of Generals Gilmore and Totten, U.S.A., and MM. Vicat, Chatoney, Rivot, and Dupont. (From *the Journal* of the Franklin Institute.)

exceeds one-tenth of the whole, furnishes the basis for a general arrangement of all natural or artificial products suitable for mortars, into five distinct classes, as follows:—

"1. The common or fat limes.
"2. The poor or meagre limes.
"3. The hydraulic limes.
"4. The hydraulic cements.
"5. The natural puzzuolanas, including puzzuolana properly so called, trass or terras, the arènes, ochreous earths, schists, grauwack, and basaltic sands, and a variety of similar substances.

"Rich limes are dissolved fully in water frequently renewed, and they remain a long time without hardening; they also increase greatly in volume, from 2 to 3·5 times their original bulks, and will not harden without the action of the air. They are rendered hydraulic by the admixture of puzzuolana or trass.

"Rich, fat, or common limes usually contain less than 10 per cent. of impurities.

"Hydraulic limestones are those which contain iron and clay, so as to enable them to produce cements which become solid when under water.

"The pastes of fat limes shrink, in hardening, to such a degree that they cannot be used as mortar without a large dose of sand.

"Poor limes have all the defects of rich limes, and increase but slightly in bulk.

"The poorer limes are invariably the basis of the most rapidly setting and most durable cements and mortars, and they are also the only limes which have the property, when in combination with silica, &c., of indurating under water, and are, therefore, applicable for the admixture of hydraulic cements or mortars. They generally contain silica (in the shape of sands), alumina, magnesia, oxide of iron, oxide of manganese, and in most cases traces of the akalies in relative proportions, which vary very considerably in different localities. Their aggregate amount is seldom less than ·10 or greater than ·25, though in some varieties it reaches as high as ·35, and even, though rarely, ·39 of the whole. In slaking, they proceed sluggishly as compared with the rich limes, and seldom produce a homogeneous and impalpable powder. They exhibit a more moderate elevation of temperature *in slaking,* and are accompanied by a much smaller increase of volume than rich limes. Like the latter, they dissolve in water frequently renewed, though more sparingly, owing to the presence of a larger amount of impurities, and like them, they will not harden if placed in a state of paste under water or in wet soil, or if excluded from contact with the atmosphere, or carbonic acid gas. They should be employed for mortar only when it is impossible to procure common or hydraulic lime, or cement, in which case it is recommended, if practicable, to reduce them to powder by grinding.

"Lime absorbs in slaking a mean of 2·5 times its volume and 2·25 times its weight of water.

"Hydraulic limes are those which readily harden under water. The most valuable, or 'eminently hydraulic,' set from the second to the fourth day after immersion; at the end of a month they become hard and insoluble, and at the end of six months they are capable of being worked like the hard natural limestones. They absorb less water than the pure limes, and only increase in bulk from 1·75 to 2·5 times their original volume.

"The inferior grades, or 'moderately hydraulic,' require a longer period, say from fifteen to twenty days' immersion, and continue to harden for a period of six months.

"The property of hardening under water, or when excluded from air, conferred upon a paste of lime, is effected by the presence of foreign substances, as silicum, alumina, iron, &c., when their aggregate presence amounts to one-tenth of the whole.

"The resistance of hydraulic lime increases if the sand is mixed in the proportion of 50 to 180 per centum of the part in volume; from thence it decreases.

"As a general rule these limes undergo, in slaking, an increase of volume inversely proportional to their hydraulicity and quickness.

"Slaked lime is a hydrate of lime.

"M. Vicat declares that lime is rendered hydraulic by the admixture of a proportion of from 33 to 40 per centum of clay and silica, and that a lime is obtained which does not slake, and which quickly sets under water.

"Artificial hydraulic limes do not attain, even under favourable circumstances, the same degree of hardness and power of resistance to compression as the natural limes of the same class.

"The close-grained and densest limestones furnish the best limes.

"Hydraulic limes lose or depreciate in value by exposure to the air.

"Arènes is a species of ochreous sand claimed to be of fossil origin. It is found in France. On account of the large proportion of clay it contains, sometimes as great as seven-tenths, it can be made into a paste with water without any addition of lime, and hence it is sometimes used in that state for walls constructed *en pisé*, as well as for mortar. Mixed with rich lime it gives excellent mortar, which attains great hardness under water and possesses great hydraulic energy.

"Puzzuolana is of volcanic origin. It comprises trass or terras, the arènes, some of the ochreous earths, and the sand of certain grauwackés, pramuntes, granites, schists, and basalts; their principal elements are silica and alumina, the former preponderating. None contain more than 10 per cent. of lime. When finely pulverised without previous calcination, and combined with the paste of fat lime, in proportions suitable to supply its deficiency in that element, it possesses hydraulic energy to a valuable degree. It is used in combination with rich lime, and it may be made by slightly calcining clay, and driving off the water of combination at a temperature of 1200°.

"Trass or terras is a blue-black trap, is also of volcanic origin. It is obtained from pits of extinct volcanoes, and has nearly all the distinguishing elements of puzzuolana, resembling it in composition and in the requirements of its manipulation, requiring to be pulverised and combined with rich lime, to render it fit for use and to develop any of its hydraulic properties. (For an analysis of them, see Burnell on Limes, Cements, Mortars, &c.)

"Brick or tile dust combined with rich lime possesses hydraulic energy.

"General Gilmore designates the varieties of hydraulic limes as follows: if, after being slaked, they harden under water in periods varying from fifteen to twenty days after immersion, slightly hydraulic; if from six to eight days, hydraulic; if from one to four days, eminently hydraulic.

"The aggregate of silica, alumina, magnesia, oxide of iron, &c., contained in these limes seldom exceeds ·35 of the whole. The proportion in the first class varying from ·10 to ·20 of the whole, in the second class from ·17 to ·24, and in the latter class from ·20 to ·35.

"Pulverised silica burned with rich lime produces hydraulic lime of excellent quality. In experiments by MM. Chatoney and Rivot, this lime hardened under water in from three to four days, and acquired in twenty-two months a hardness superior to Portland cement. The weight of the powdered lime never exceeded four times, and never less than one half, that of the powdered silica.

"Hydraulic limes in their composition, and in their value for application to the purposes of construction, and in their geological position, occupy an intermediate place between the common or fat limes and the hydraulic cements. They are found in the United States, in numerous and extensive deposits. Hydraulic limes are injured by air slaking, in a ratio varying directly with their hydraulicity, and they deteriorate by age. For foundations in a damp soil or exposure, hydraulic limes must be exclusively employed.

Cements.

"Hydraulic cements contain a larger proportion of silica, alumina, magnesia, &c., than any of the preceding varieties of lime; they do not slake after calcination, and they are superior to the very best of hydraulic limes, as some of them set under water at a moderate temperature (65°) in from three to four minutes; others require as many hours. They do not shrink in hardening, and make an excellent mortar without any admixture of sand.

"Roman cement is made from a lime of a peculiar character found in England and France. derived from argillo-calcareous kidney-shaped stones, termed 'Septaria,' and when mixed thick it solidifies in a few minutes either in air or water; hence, for some purposes, it is of great utility, and for others its use is impracticable.

"The manufactured article takes its name from the locality of the store, as 'Boulogne' or 'Sheppy.'

"Rosendale cement, from the township of Rosendale, N.Y., is derived from the water limestone of the Helderburg group, *Ulster county,* New York.

"Portland cement is made in England and France from an argillo-calcareous deposit, which is burned and ground up for cement in its natural state, without the addition of lime. It requires less water than the Roman cement. It sets slowly, and can be remixed with additional water after an interval of twelve or even twenty-four hours from its first mixture.

"The property of setting slow may be an obstacle to the use of some designations of this cement, as the Boulogne, when required for localities having to contend against immediate causes of destruction, as in sea constructions having to be executed under water and between tides. On the other hand, a quick-setting cement is always difficult of use; it requires special workmen and an active supervision. A slow-setting cement, however, like the natural Portland, possesses the advantage of being managed by ordinary workmen, and it can be remixed with additional water after twelve or even twenty-four hours.

"Artificial cement is made by a combination of slaked lime with unburnt clay in suitable proportions, burning the mixture in a kiln or furnace and then grinding it, or by substituting for the lime a carbonate of a lime that can be pulverised without burning, or by using artificial puzzuolana, or by adding silica in a soluble form to a paste of common lime.

"Artificial puzzuolana is made by subjecting clay to a slight calcination.—(Pambour.)

"Salt water has a tendency to decompose cements of all kinds.

Mortars.

"Lime or cement paste is the cementing substance in mortar, and its proportion should be determined by the rule, that the volume of the cementing substance should be somewhat in excess of the volume of voids or spaces in the sand or coarse material to be united. The excess being added to meet imperfect manipulation of the mass.

"Hydraulic mortar, if re-pulverised and formed into a paste after having once set, immediately loses a great portion of its hydraulicity, and descends to the level of the moderate hydraulic limes. A great destruction of the hydraulic principle therefore results from any disturbance of the molecular arrangement of the mortar, after crystallization has commenced. This is what occurs with the intermediate limes, which take initial set promptly and firmly, but which are subsequently thrown down by the slaking of the impure caustic lime which they contain.

"All mortars are much improved by being worked or manipulated, and as rich limes gain somewhat by exposure to the air, it is advisable to work mortar in large quantities, and then render it fit for use by a second manipulation.

"White lime will take a larger proportion of sand than brown lime.

"The use of salt water in the composition of mortar injures the adhesion of it.

"*Mortar.*—When a small quantity of water is mixed with slaked lime, a stiff paste is made, which upon becoming dry or hard, has but very little tenacity, but by being mixed with sand or like substances, it acquires the properties of a cement or mortar.

"The proportion of sand that can be incorporated with mortar depends partly upon the degree of fineness of the sand itself, and partly upon the character of the lime. For the rich limes, the resistance is increased if the sand be in proportions varying from 50 to 240 per centum of the paste in volume, beyond this proportion the resistance decreases.

"*Stone mortar.*—325 lb. cement, 120 lb. lime, and 14·67 cubic feet of sand.

"*Brick mortar.*—325 lb. cement, 120 lb. lime, and 12 cubic feet of sand.

"*Brown mortar.*—Lime one part, sand two, and a small quantity of hair.

"Lime and sand, and cement and sand, lessen about one-third in volume when mixed together."

Analyses of Hydraulic Limes, Cements, Trass, and Puzzuolana.

No.	Specific Gravity.	Carbonic Acid.	Potash, Soda.	Silica, Alumina, Iron.	Lime.	Carbonate of Lime.	Magnesia and Carbonate.	Acids, Chlorides, Phosphates, &c.	Where from.
1	2·652		·62 ·88	25·20 6·16 2·02		58·84	10·38	·48	Utica, Illinois.
2	2·678		·40 12·10	19·66 3·14 3·86		40·54	17·98	·72	Sandusky, Ohio.
3	2·680		1·54 4·64	24·74 16·74 6·30		41·80	4·10	2·22	Cumberland, Md.
4	2·753			17·84 4·60 1·70		58·25	11·16	·74 3·26	Shepherdstown, Va.
5	2·844			18·52 2·18 1·86		43·30	26·04	1·96 4·24	High Falls, Ulster, co., N. Y.
6	2·735			29·34 5·74 1·76		33·54	20·80	1·02 5·80	Do. do.
7	2·822			19·64 7·52 2·38		30·72	35·10	·64 4·10	Do. do.
8	2·761			18·46 4·22 2·32		37·50	35·62	·20 1·68	Do. do.
9	2·786			27·70 2·34 1·26		46·00	17·76	·26 4·02	Do. do.
10		31·00		18·00 5·25	30·20		·20		Sheppy, Eng., cement stone.
11		29·00		17·75 6·00	35·00		·50		Nos. 1 & 2.
12		29·77		12·00 8·80	34·08		1·52		Southend, England, do.
13		31·00		24·00 1·31	30·50		1·04		Yorkshire, do.
14		22·75		9·375 17·75	29·25			7·50	Harwich, do.
15			7·0 1·0	57·0 5·0	2·6		1·0		Trass.
16			1·4 4·0	44·5 12·0	8·8		4·7		Puzzuolana.

Nos. 1 to 9 were analyzed by Prof. E. C. Boynton, Miss., and Nos. 10 to 16 *by Berthier.—Civil Engineer and* Architect's Journal.

DIVISION TWELFTH.

BRIDGES—ROOFS—RESERVOIRS.

108. *On Rigid Suspension Bridges of large Span, Constructed of Iron and Steel, or of Wood and Iron combined.*—The following is part of a paper read by A. Sedley, Esq., before the "Inventors' Institute," and reported in the "Scientific Review:"—"In my humble opinion, urged with all due deference to the illustrious body of engineers of Great Britain, the roadway of a suspension bridge should be so built up as to be capable of carrying its own weight, at least without sensible deflection, even for the greatest spans that can be attempted. At the first blush of thought this may seem to be almost impossible, but on reflection it will be seen that it is easy enough. We have already at Lambeth the germ of this idea; and, perhaps, plain and simple as some call it, there is no bridge over the Thames which has so much useful novelty about it as the suspension bridge by Mr. Barlow. The engineer may study here a new principle, one which will, I venture to say, with some improvements, lead to the construction of spans which are impossible on any other than rigid suspension principles. In explaining my improvements I shall allude further to this. In looking into the work of Mr. E. Clark, 'The Conway and Menai Bridges,' I find, page 47, Mr. Stephenson is asked about the practicability of the span. It appears that it was in contemplation at that time to convert Telford's suspension bridge into a rigid bridge by means of trussing; of this I think it only remains to be said that it was found it could not be well managed.

"I do not propose to go into the question of rigid girder bridges without suspension, because they involve different principles of construction, and cannot well be built without centrings, to which in my models I shall particularly direct your attention, whereby very great expense is saved.

"The suspension principles by Brunel, in the Saltash Bridge and the Chepstow Bridge, have been so carefully explained in papers read before the Society of Civil Engineers, that I will not venture to trouble you with remarks respecting these, further than asking you to notice that the heaviest weights in this construction are towards the centre, in the same way as in all other rigid girder bridges, which is the reverse of my principle. You will perceive that I have not gone into the matter of strains, sectional areas or weights, tensile or crushing strains. This I have avoided, because there are tables for calculating all these, and formulæ also which apply to most of them; but I am one of those who think there is as much mechanical common sense in matters of this kind as in any other.

"Let us, for example, consider a suspension bridge capable of taking a first class locomotive and tender only, at a rate of fifty miles an hour. We will assume that the locomotive weighs 40 tons, that the bridge is 16 ft. wide, and that, in addition to the weight of the locomotive, something is due from its momentum, part of which is expended in the air, and part of it in the metals or substructure of the bridge. Now, I venture to submit that serious damage would occur to any suspension bridge, constructed on any known principle, if a train ran at a quick pace. This weight of 40 tons is distributed over a space of 16 ft. by 50 ft., making the load 112 lbs. per super foot of surface; to this must be added an extra weight for the momentum attached to the speed of the engine. If we imagine the engine to be to a certain extent moving in the deflection of a cannon ball—*viz.*, that its tendency is downwards in a parabolic curve, instead of upwards—it will be seen that the additional weight caused from this must be very great; and it is this frictional weight which causes the vibration and oscillation which is so dangerous to the catenary principle and roads as now constructed. The action of the rolling weight would therefore tend rather to produce oscillation than to allay it, when any regular or irregular strain may be put on the bridge; and no guys, chains, or stays, will have the effect of producing rigidity, but merely become an incumbrance and extra weight on the chains, without at all adding to strength. It would be, in fact, like putting 50 lbs. weight on a man's shoulders in order to add to his strength, which certainly would be a novel mode of proceeding.

"There are other systems of suspension bridges, models of which were exhibited at the International Exhibition; and of these it may be said fairly, without entering into detail, that *they are only as strong* as the weakest part of them. I say this because their principles of suspension and support are so divided that much weight is added, without conducing in any way to give additional strength.

"According to Mr. Clark's admirable work on the Menai Bridges, Mr. Stephenson and himself often considered whether it would be practicable to convert the Menai Suspension Bridge; but they seem to have arrived at the same reasoning that I have just explained to you—that unless the platform was in itself sufficiently rigid to be self-supporting, all that could be done would but add to the weight of the bridge, without conducing one atom to its strength. Even Telford himself would, I venture to say, have hesitated to recommend suspension as a proper principle for locomotive and railway traffic.

"There are so many hostile forces put into action by a train passing over a bridge of large span, that in my mind I have thus classified them:—1. the percussive, 2. the re-percussive, and 3. the concussive action. The percussive action I consider to be the first wave which, arising at the entry of a train on to the bridge, operates in expending its force in driving the platform against the opposite abutment, contracting the platform girder in its width slightly at top, and widening it at the bottom; the re-percussive force is the echo or reverberation of this wave backwards; and the concussive action is the tremulous effect which is generally felt as you approach the centre of the bridge. I am, of course, supposing this. Taking the case of a properly constructed bridge, where the principles are truthful, and where the material has not been cut too fine, but where the metal is becoming fatigued, or nearly so, these strains are very unequal, and the vibrations due to the actions above described begin and cease in a very unequal manner, and consequently are most destructive in their effect.

"The theories and laws of compression and extension in cast-iron are so well known that it is not necessary for me to enter into them, as there are, I am sure, gentlemen in this room who will tell me much more about them than I know myself.

"The most important considerations in a bridge of large span are—1. The weight of material to be employed in the girders, especially towards the centre, for here the greatest strength is necessary; consequently, according to systems at present employed, great provision must be made for the extra strain exerted in and by the centre, by the weight of the material necessary to be placed there to support it, and the required load of train weight besides. 2. The necessity of constructing such bridge of great lightness and rigidity. One of the points mostly insisted upon by engineers and contractors is duplication and re-duplication of parts, so as to afford an easy method of construction. It is possible that in what I submit to your notice, it may be urged that there is an excess of metal, as they are only small models. This may indeed be the case, but in the full size it would not be so.

"I may mention to you that I have already constructed a small bridge for foot-passengers with a clear span of twenty-eight feet. It is made of common fir, and the sectional area of the two girders is only 160 inches, which is less by one half than any other bridge of which I have been able to obtain a measurement.

"This bridge has borne, with a deflection of two inches, seven tons of materials placed on it. It was afterwards tested by twenty men jumping in the centre, when the deflection or spring was five-eighths of an inch, but as much upwards as downwards. The total weight of the bridge is sixteen cwt. It is only roughly put together, and much weakened by mistakes made, and which are always inevitable in a first trial of a new system of construction.

"It is a combination of the tubular, girder, and suspension principles; unites great simplicity with easy and economical construction; and the combination differs entirely from any employed up to the present time. No intermediate piers or subaqueous works are necessary.

"Such a bridge may be built as easily at a height of 500 feet above the level of the river or valley, as at a height of 25 feet; and wood, iron, and steel may be used in combination, or in large spans iron and steel only.

"I am fully aware of the risks of crushing and tensile strains, which are considered imminent in a structure of this kind, but am certain that all these are provided for. One thing is perfectly clear, that if it be an ascertained and easy matter to raise and *launch a vessel of 5,000 tons* 400 or 500 feet long, and weighing treble the weight of this bridge, there can be no difficulty in constructing and placing in position a bridge not exceeding one-third of the weight, and possessing three times the strength of such a structure as a vessel. In all combinations of this kind, compactness, rigidity, and a due relation of parts and strength, are features of the first importance; and with a view to the application of these, I have studied as well as I could all the structures and various systems adopted by the most celebrated engineers at home and abroad, and naturally availed myself of the advantages to be derived from the constructive features of these bridges or viaducts."

109. *Trussed* versus *Plate Girders.*—"The broad principles," says a writer in the 'Mechanics' Magazine,' March 10th, 1865, in an article under the above title, of which we here give extracts,—"governing the grand art of bridge construction may be regarded as settled by the dictum of men of science, who have in many instances arrived at similar conclusions from data so entirely dissimilar, that the strongest confirmation is afforded of their general accuracy. But other questions than those connected with strength begin to start up day by day—considerations which urge themselves on our attention with a pertinacity which will brook no denial of their claims to be heard. Time was when so long as a span was crossed, men cared little as to the æsthetical laws observed or broken in the crossing. Funds were lavished and expense was seldom thought much about. A ton or two of iron here and there more than was absolutely necessary was a matter of only secondary consideration. As to durability, it is doubtful if engineers ever gave the question a thought, or permitted it to influence their proceedings in any way. So long as a bridge possessed such a margin of strength as would enable it to cope with the more obtrusive forces of destruction involved in the presence of intrinsic weight in the structure itself, and external weight in the passing loads, all was well, and little attention was paid to the possible effects of the more subtle agencies of destruction brought to bear by chemical action, and continuously recurring vibrations. The conclusion was one of the most natural possible; it followed as a direct consequence of the almost total dearth of information; and even now, after the lapse

of twenty years of iron-bridge building, the subject is only just beginning to receive the attention it really deserves.

"The opinions of Mr. Fairbairn as the apostle, if not the parent, of the tubular girder, are worthy of every consideration, and when we find him lifting up his voice to protest against the use of the lattice girder, it is reasonable that we should listen to his warning. Yet the employment of the trussed girder goes on apace, while the tubular girder would seem to be simply tolerated as an invention likely to serve a good purpose under exceptional conditions, but by no means to be resorted to, otherwise than as a last resource. We are speaking now, be it observed, of works of considerable magnitude, not of the small structures which abound in every country blessed with a railway system. We cannot resist the conclusion that Mr. Fairbairn is perfectly right in maintaining the high character of the tubular girder; but we also believe that the practical engineer is correct in refusing to adopt it habitually. The apparent anomaly contained in these statements will vanish when we understand that Mr. Fairbairn, and many other gentlemen of talent and skill who coincide in his opinions, regard the entire question from an antiquated point of view. With them, the strength of a girder is a point to which every other consideration must be subordinated. The engineer, on the contrary, well up in modern practice, perceives that it will not do to erect a structure which shall resemble one of the creations of Fuseli in its real hideousness, no matter how beautiful it may be as an example of the application of sound theory to constructive art; neither will it serve his purpose or that of his employers to spend more money than may be absolutely necessary. In addition the teachings of such experience as we have as yet had placed at our disposal goes to show that the tubular girder, and to some extent the plate girder as well, contains in itself the elements of its own destruction. . . . .

"As to expense, under any circumstances the tubular form is perhaps the most costly that it is possible to adopt. Without the cellular system the girder loses at least one-half of its advantages, and yet these same cells run away with nearly, if not quite, one moiety of the pecuniary expenditure on labour. The use of self-acting punching machinery can do little to mitigate the *evil.* *The riveting* can hardly be performed otherwise than by hand, and the small size of the cells, and the difficulties met with in 'holding up' the rivets to the strikers, are too well understood by the practical man to require much comment at our hands. We can state with confidence that the expense of such girders must be nearly £5 per ton greater than that of lattice beams of equal strength, and from £1 to £2 greater than that of the simple plate girders occasionally used for considerable spans. In addition to the question of first cost, however, we find that the difficulties of repair are excessively great. The time has not yet come when it will be found necessary to replace corroded plates in the Britannia or Conway tubes. Indeed, the plate iron bridge is of such comparatively recent invention that this matter of repairs has been tacitly handed over to a succeeding generation as something with which we have nothing to do. It is possible that the conclusion is premature. In any case it will be found that the cutting of one plate out, and the replacing it with another, will be a serious undertaking; and it is certain that, the initial powers of resistance of the girder once impaired, they can never be restored by any practicable system of patching. The cutting off of 'snap' points, and the punching out of rivets, is not calculated to improve the quality of a plate; and we much fear that the tacking on of new material to that already grown, not grey, but rusty in service, can only tend to make an original rent very much worse. So long as wrought iron is exposed to the direct influence of an atmosphere charged with moisture, its corrosion must, of necessity, be rapid. The only practicable protection is paint; but the cells of a tubular girder once finished, anything like satisfactory access to them is at an end. Damp and air will penetrate, however, where a boy with a can of paint cannot; and as the protecting medium will not last for ever, it follows that corrosion must sooner or later destroy the plates. Already a quantity of scale has been removed from the Britannia bridge, representing a quantity of iron equivalent to a bar 4 in. in diameter the length of the entire span. Of the state of the cells, we know absolutely nothing. The simple plate girder is not much better off; although accessible in the main, it presents such an immense comparative surface to the influence of the weather, that even with every caution the iron is liable to be eaten away with surprising rapidity. When we take the extreme thinness of the webs into consideration, it is easy to see that the margin afforded to compensate for this action is exceedingly small.

"The great defect of the trussed girder is the want of vertical stiffness. Recent improvements in the distribution of the material have done much to overcome this objection; and yet more has been done by accurate fitting and careful workmanship. The origin of the lattice girder can be traced to America, and we believe it was invented by an engineer named Town. It is hardly necessary to state, that in the first instance it was invariably made of wood. The first English engineer to adopt it in iron, was Sir John MacNeil, who constructed a bridge of the kind on the Dublin and Drogheda Railway, of about 40 ft. span, in 1843, with the best results; since then the system has risen and fallen in estimation. It is now rising again; and it is probable that it will yet take the place it really deserves. According to Mr. Fairbairn, it is, perhaps, true that initial strength of the lattice as compared with the tubular cellular girder, is but as ·84 is to 1. It remains to be seen, however, whether this ratio can be regarded as constant through a long series of years. We have every reason to believe that it cannot. The ease with which the lattice, or more properly the trussed girder, can be painted, the facility with which repairs can be effected without in any way interfering with the traffic, and the greater thickness of the bars of which it is composed, are all so many points in its favour. The ultimate strength of bars, too, as compared with plates, is nearly in the ratio of 13 to 12, a consideration worth something. Special machinery can be applied to the formation of trussed girders with unparalleled ease, while the facilities which they present for export in the small size and exact duplication of their parts, have secured them a preference which they well deserve for colonial lines. As to beauty, there can be no question that the system affords opportunities for the carrying out of the true principles of æsthetical art which are absolutely unrivalled."

110. *Large Span Roofs.*—"At a recent meeting of the Society of Civil Engineers in France, M. Lehaître brought forward a notice of a system of suspended roofing proposed by MM. Lehaître and de Mondésir. Owing to the use of iron and cast metal, roofing has lately made great progress. It, has, nevertheless been

impossible, within a reasonable outlay, to exceed a span of 30 to 35 metres, or exceptionally, and with considerable sacrifice, of 40 metres to 45 metres. It is very evident that it would be of great improvement to be able to cover large spaces, as market-places, railway stations, hippodromes, &c., without the use of intermediate supports, which represent a host of inconveniences it would be useless to recall here. MM. Lehaître and de Mondésir have sought the solution of the difficulty in the use of suspending cables, the application of which has been hitherto limited to suspension bridges. The principal difficulties which attend the use of cables in suspension bridges completely disappear from their use for roofing. The strain they have to sustain being no longer variable, there is no fear of those oscillating movements which are so dangerous, and which considerably increase the cost of maintenance of the flooring. The roofing cables can always be made fast to open work inside the bearing walls. The advantages of this new application are apparent. One of the foremost is the economy induced, a consequence of the light weight. It is not the object of the authors of the system to make it a matter of speculation, but on the contrary, they desire to popularise it by teaching it to all competent men, and submitting it to the appreciation of learned societies. It may be adapted to the construction of large circuses, either with or without centre columns; of naves lighted from the top, either though glazing on the coping or through vertical lights; of a series of longitudinal and transverse galleries, supported by pillars alternately arranged at distances of from 30 metres to 75 metres.

"A short description was furnished of proposed plans for a circus of 200 metres interior diameter, and for one of 100 metres interior diameter, with a pillar in the centre; also for a circus 100 metres interior diameter, and a market-place 50 metres interior diameter, with granaries or shops, without internal support. In the two first structures the suspending chains are secured to a sheet-iron hood on the top of the centre column, passing over friction rollers placed on the bearing walls of a circular gallery of masonry 28 metres wide, which runs round the space to be covered in, and are fastened in a gallery easy of access, so that they may be examined. These suspension chains, with the help of iron supports bound together, bear up the principal rafters.

which are of iron, and these support the purlins, battenings, and a covering either of sheet-iron or zinc. The roof is arranged in terraces, and the lights are introduced in the upright spaces intervening between every two successive terraces. MM. Lehaître and de Mondésir compute approximately that such a structure—from the ground level (not inclusive of foundations), constructed of iron wire which will bear a strain of one-tenth its ultimate resistance, the column being subjected to a maximum weight of seven kilogrammes per square centimetre at its base and of four kilogrammes at its summit, of zinc No. 14, the masonry of freestone—might be erected at less than half the cost of ordinary market and assembly places. A circus 100 metres in diameter, built as substantially, with a central column of cast iron instead of masonry, would cost 96 f. the square metre, at the outside. One of the same dimensions without a central pillar, lighted by a central lantern borne by the roof attached to the suspension chains, would cost 90 f. per square metre. A market-place 50 metres in diameter, on the same system, would cost 70 f. the square metre. In these erections, in which the roof is suspended, the weight of the bearing walls of the outside gallery is utilised in resisting the tension of the chains.

"There then follows an account of the adaptation of the system to rectangular buildings. For a rectangular room, 75 metres in width, with lateral buildings, the bearing-walls of which serve as grapplings for the chains, the chains are supported by pillars erected on the bearing-walls. With the help of suspension rods they bear the transverse rafters. That the pillars may not be raised too high, that portion of the rafter which is nearest them is borne by rods submitted to a traction strain, and towards the middle they are supported by upright rods which are compressed or tightened. The distance of the cables is regulated by the length of the purlins, fixed in the plan at 12 metres. Adhering to these conditions, the square metre covered in, including annexed buildings (above the ground level) comes to 75 f.; the lights are introduced in the copings of the roof. By increasing the height of the pillars over which the chains pass, vertical lights might be contrived, but the cost would then be 85 f. the square metre. A rectangular room 150 metres in width, lighted *from the coping, would* be constructed at 85 f.; lighted with vertical windows at 95 f. the square metre. For spans of 250 metres, the cost would be only two-thirds of the ordinary cost of spans of only 30 or 40 metres, constructed on the old system, not surpassing 160 f. Lastly, the authors of this memoire exhibit a proposed arrangement for buildings with longitudinal galleries 40 metres, and transverse galleries 30 metres in width, and for buildings with longitudinal galleries 75 metres, and transverse galleries 40 metres in width, specially suitable for exhibition buildings, markets, or large shops. These galleries are arranged with an alternate system of supports, and form a series of apartments arranged in squares like a chess-board. The span of the purlins would be too great were the chains suspended only one way; they are, therefore, hung across each other longitudinally and diagonally. They are connected at the top of each pillar, and being diametrically opposite to one another, the horizontal strain is neutralised, and the vertical component only remains, in a direct downward pressure on the pillar. All the chains are, as in the preceding instance, grappled to the bearing-walls of the side buildings. The main rafters, fixed in the same plane as the chains, are borne by suspension rods or props, and receive the purlins and glazing. The rain overflow is conducted through the inside of the pillars. This design, as light as it is graceful, forms a kind of series of vaults of ribs, the rafters of which, placed in the plane of the diagonal chains, form the intersections. The cost of the first construction, 45 metres, is valued at 55 f., that of the second, 75 metres, at 70 f. All the estimates would, of course, be lowered, if, instead of zinc, freestone, and cast metal, there were employed bitumenised pasteboard, and deal for the timber work. The expense of the two last proposed erections, applicable to exhibition buildings, would be 35 f. (galleries of 40 metres) 45 f. (galleries of 75 metres)."—*Building News.*

111. *The Sheffield Reservoir Accident.*—"The cause of the giving way of the embankment of the Bradfield reservoir, near Sheffield, by which 238 lives were lost, and £400,000 worth of property destroyed, in March, 1864, has been keenly speculated upon by engineers. The Water-works Company consulted several of the most eminent hydraulic and other engineers of the day, and the report of those gentlemen has been issued to the shareholders. The document is prefaced by a correspondence with the

Home office, in regard to the resumption of work on the Agden reservoir, which was stopped by the directors immediately after the accident at Bradfield. Mr. Rawlinson (Government inspector) stated at the inquest that the substance of that bank was as 'porous as a sieve.' He attributed the failure of the Bradfield bank to a fracture or dislocation of the pipes, which are imbedded in the solid earth beneath the base of the bank. Sir George Grey says, in his reply to a letter from the directors, after they had received the report of the engineers—'I am to acquaint you, in reply, that as Sir George Grey understands the works at Agden to be now precisely in the same state as when they were inspected in March last by Mr. Rawlinson, and as his report of the result of his inspection of these works is in the possession of the directors, together with the report of Messrs. Rawlinson and Beardmore on the bursting of the Bradfield reservoir embankment, and a copy of the evidence given at the inquest held at Sheffield, Sir George Grey does not see what additional information could be obtained by a further investigation made at the instance of the Government. The directors, with this information in their possession, having now decided, as you inform Sir George Grey, that they are justified in proceeding with the Agden embankment, Sir George Grey can only remind them that he has no power to interfere with their decision; and that if the works are proceeded with it must be upon the undivided responsibility of the Company, and without any sanction, expressed or implied, on the part of Her Majesty's Government.' In their report to the shareholders the engineers (Messrs. Simpson, Hawksley, Bateman, Fowler, and Harrison) enter at some length into the circumstances attending the construction of the Bradfield reservoir, and conclude as follows:—'The filling of the reservoir commenced in June, 1863, on the occasion of a heavy flood, and from that time, with some intermissions, the reservoir gradually increased in depth, and at the time of the accident, on the 11th of March, 1864, it had attained to a height which was within three inches of the top of the weir. During the whole of this period no imperfection of any kind had been perceived, the embankment and the reservoir being absolutely water-tight; for though a small spring of ochreous water issued from a shale bed in the escarpment *on the south side* of the river below the bank, yet this equally appeared whether the reservoir was full or empty, and was, therefore, fed from other sources. Moreover, this water still continues to issue, although the reservoir has been emptied of its contents for many months. There was no fracture of the pipes, nor any creep of water along the outside of them. *The embankment was composed of materials which would not have slipped if the base on which it rested had been immovable. We must, therefore, look for causes other than supposed imperfections in the quality of the materials or workmanship for the failure of the reservoir.* The weather during the fortnight previous to the accident had been exceedingly wet, the rain so swelling the rivers as to inundate all the low country in the East Riding of Yorkshire. It is in such seasons that masses of earth, commonly called 'landslips,' become saturated with water or lubricated on their bases, and, although at other periods comparatively or altogether stable, now begin to move. That the ground outside the embankment has moved is evident, not only from the tears and fractures which are to be observed in the lower part of the mass, but also from the significant fact that one cottage situated high on the hill, and another nearer to the foot, and both remote from the bank, give unmistakable proofs of the recent movement of the ground on which they stand. From the testimony of the occupiers of these cottages this movement must have immediately preceded or *been concurrent* with the bursting of the reservoir. After a full consideration of these and other collateral circumstances, we are unanimously of opinion that the accident was occasioned by a landslip which occurred in the ground immediately on the east side of the embankment, and which extended beneath a portion of its outer slope, involving in its consequences the ruin of that portion of the bank, and producing the catastrophe which followed. To this conclusion we severally came on our first examination; and every subsequent investigation, and the more intimate acquaintance we have since acquired, with all the evidence and facts connected with the subject, have only the more firmly convinced us that to no other cause can the destruction of the reservoir be rightly attributed. We are, moreover, of opinion that all the arrangements made by your engineers were such as might have been reasonably expected to have proved sufficient for the purposes for which they were intended, and that if the ground beneath the bank had not moved, this work would have been as safe and as perfect as the other five or six large reservoirs of the Company, which have been constructed in a similar manner, and which have so long supplied the town of Sheffield and the rivers Rivelin, Loxley, and Don with water. With regard to the propriety of repairing the broken embankment, or of abandoning it and forming another elsewhere, we are not in a condition to report fully on this question.'

"Thus in a professional point of view the interest in the bursting of the Bradfield reservoir is as great, if not greater than ever; for the more doctors have been called in successively, the more they appear to have disagreed as to the true reason of the disastrous failure of the work.

"Mr. Rawlinson, C. E., as it will be remembered,* as stated in our columns some months ago, attributed the failure to fracture of the main pipes under the thickness of the embankment. This solution, never to our mind probable, was negatived subsequently by actual observation of the bare laid pipes. But Mr. Rawlinson also stated that the earthwork of the embankment was very imperfectly executed, both as to its material and the way in which it was laid in; that, in fact, it was as 'porous as a sieve.' In this, as a general statement, he was unquestionably right, as verified by our own personal and careful examination of the work. Many other more or less random opinions were uttered as to the cause of the giving way of the embankment, at the date and subsequent to the inquest.

"We ourselves formed a decided view as to the true causes of the catastrophe, and explained them in former pages of this Journal, with the aid of diagrams.

"The essence of our solution was this, that the porosity of the inner or up-stream prism of the embankment, formed as it was of alternate layers of earth and of loose stones, *gradually* permitted the whole of that prism to get water-soaked, and so to bring the water pressure *as a hydrostatic force* at last right against the up-stream vertical side of the puddle wall in the embankment. When that took place, the whole resistance of the embankment became reduced merely to that of the puddle wall and the outer prism. These, it admits of demonstration, were not alone capable *of sustaining* continuously the pressure of the water in the reservoir. The outer prism was bent or pushed partly over; the top was thus lowered, and the first water that began to run over, or wash over in large disturbed waves, rapidly led to the final catastrophe, which in all likelihood *was* a great slipping of the toe and down-stream front of the embankment, after the first few minutes of the rush over and down the face had weakened, and in part excavated, the down-stream toe of the bank. This, however, is a different affair from the utterly improbable hypothesis of a landslip *under the embankment.*

"The portion of the last report of the five engineers, which we have placed in italics, is one of the most singularly loose, gratuitous, and unsupported statements we have ever seen in such a document. What proof is offered or even suggested that the materials of the embankment would not have slipped if the base on which it rested had been immovable? and who has ever said, on good grounds, that it did slip? How adroitly, therefore, the flank is turned of the real point at issue by taking all this for granted, and then triumphantly adding, we must therefore look for other causes than *the supposed imperfections of the materials or workmanship for the failure of the reservoir.*

"Nothing, as it occurs to us, can be less consequential or convincing than the attempts at circumstantial argument, by which it is sought to show that the whole affair arose from a landslip at or rather under the outer toe of the bank. True it was that slippery soil had always existed at the one side of the valley, just *below* the bank; but its condition, to a critical eye, after the failure and inundation was precisely the same as it was before these. There was no sign of any fresh, sudden, or great slippage, nor indeed of any landslip at all; and had any such occurred, as its line of movement must have been transverse to the valley or along the line of the outer toe, and towards the centre of the valley into which such a landslip must have precipitated itself, its effects would not have been to weaken, but actually to increase the stability of the embankment.

"When the rush of water took place, and enormous masses of earth, &c., were thrown forward, and the whole of the valley flanks adjacent shaken and disturbed, the slippery side did no doubt, more or less, descend bodily, though very slightly, and the cottages upon this side came with it by some small amount, and possibly cracked their walls more or less. But what trustworthy evidence is there that they were not cracked before? How extraordinary an example of the *post hoc propter hoc* mode of reasoning it is to take these events, all of which may be just as easily viewed as consequences, for the causes of the phenomenon!

"There is nothing in the fact that the reservoir was quite full for some short time and appeared to stand well, and yet failed at last, that *necessarily* supports the view of the five engineers' report. On the other hand, this is precisely the successive order of facts that we should expect as consonant with the solution we have given, and to the truth of which they present strong corroborative evidence.

"While the *whole* embankment, inside and outside prisms, resisted the water pressure, it remained safe and sound. The soakage of the inner prism was a work of time, the duration of which depended on the greater or less porosity of the strata of its material. Until the water as a *continuous fluid* had worked its way fairly into the upper face of the puddle wall, all may have been well. At length, however, the continuity of fluid involved continuity of hydrostatic pressure, transferred now from the outside of the inner *slope* of the inner prism to the nearly vertical inner face of the contained puddle wall; and then the consequence was as we have indicated before.

"The assertions of the five reporters (for we cannot dignify them with the title of conclusions) that the work was all well done, and deserved no exception to be taken to it—that the failure arose from this assumed landslip—and that it is vain to look for any other cause for it—may be very polite to the reputations principally concerned, and very politic on the part of hydraulic engineers in general anxious to allay the alarm of the public as to big reservoirs and embankments; but we take leave to say is very far from being a philosophically true and searchingly exact statement of the facts, or a logical consideration of the conclusions to which their accurate statement and colligation should have led.

"We therefore venture to commend to such of our readers as are professionally or otherwise interested in the Sheffield accident (if so it may be called) to turn back to our previous article on the subject and reperuse it, with the report above referred to, before them, and draw their own conclusions."—*Practical Mechanic's Journal.*

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DIVISION THIRTEENTH.

AGRICULTURAL MACHINERY.

112. *The Royal Agricultural Society's Meeting at Plymouth.*—In this department the feature of the year was, as usual, the above; from a notice of which in the "Practical Mechanic's Journal" we take the following:—"This meeting, the visit of the Prince and Princess of Wales, and the arrival of the French squadron at Plymouth, have created an unusual amount of public interest to be directed to the western metropolis. Although no doubt desirable for the general good of agriculture that the meeting of this powerful society should be held in all parts of England, it is clearly a loss to the society, and to the bulk of exhibitors, when the meeting happens to take place in a district so remote as the extreme west. The visit of the Prince and Princess of Wales, and the accidental arrival of the French squadron, have, however, contributed to enlarge the number of visitors; but nothing like the numbers attained in the central counties can be this year expected. The railroad accommodation is too scanty to supply the desired number of shilling visitors.

"The implements exhibited, to which our attention has been exclusively directed, show no falling off in point of numbers, there being no less than 4,023 separate entries. We are glad to recognise the names of all the large firms as exhibitors, and the stands also disclose a fair number of local names. The show each year seems to bring to light a number of small makers in the separate localities, showing that in the aggregate agricultural implement makers form no contemptible section of the community.

"Our readers are aware that the society takes a certain class of implements into examination each year. The prizes at Plymouth are given to drills, horse hoes, haymakers, horse rakes, grass mowers, and reaping machines; and such numbers of these implements have been exhibited and tested as to tax severely the powers of the judges, whilst the exhibitors in some instances loudly complain that sufficient time is not given to thoroughly test each machine.

"The reaping and mowing machines have this year attracted greatest notice. Many farmers who have quite made up their minds to mechanical cutting, have postponed their decision as to the machine to be purchased until after the Plymouth show. We fear, however, that the trials have been conducted under such unfavourable circumstances as to render the result of comparatively small value.

"Few of the tipping-platforms could work without frequent stoppages, the crops being too heavy and tangled for them. In ordinary crops, however, the tipping-platform, if properly constructed, greatly facilitates delivery. Wood's and Hornsby's platforms acted well, and Picksley and Sim's machine made very satisfactory work. The best, however, was that of Cuthbert's simply-made machine, with a flat immovable platform, the cutting being beautifully done, and the delivery, in small bunches ready for binding, accomplished with regularity and apparent ease. In Hornsby's new reaper, a rakeman gathers the crop to the machine, catches the cut corn upon a tipping platform, and by a movement of his foot drops the bunch upon a number of endless chains on a lower platform, these delivering the bunch at one side out of the next track of the horses. This machine has the advantage of the rakeman's discretion in separating and lifting up the tangled corn, and forming it into a proper bunch, while the man is relieved of the pushing the cut corn off the platform. But the sheaves are not only laid in good form for binding—an important point, both in facilitating labour and securing most of the ears at the top of the 'stook' when set up—they are also delivered completely out of the way of the next course of the machine; so that, as with all side-delivery reapers, the machine has never to wait for the precise number of hands proportioned to the crop, and barley or heavy wheat may be left for any length of time untied and drying under sun and air. Self-acting sheafing machines have been introduced since the last (or Leeds) trial of reapers, and with considerable success. Samuelson's automatic rakes, revolving something like four sails of a windmill on an axis nearly vertical, and guided by a circular cam so as to enter into the crop endwise, lay the corn back over the cutters, and then clear off the cut sheaf by sweeping radially over the platform, worked with a quiet motion favourable to very ripe grain.

"Wood's machine, with a single rake-arm, revolving in a similar position, but in conjunction with an ordinary reel on a horizontal axis for bringing the corn upon the platform, has also great merit; and the delivery can be delayed at pleasure by the driver, to form sheaves of any size. Burgess and Key's machine made the cleanest and best cut, but the breadth taken proved too much for the delivering powers of the rake; and the velocity of the rake (revolving in the place of one of the real boards) caused it to toss up into the air much of the corn that should have been quietly laid in neat sheaves.

"One point made apparent during the trials is, that sheaf delivery, if not effected by too sudden and violent a motion, thrashes out less grain than swathe delivery does, as only the outer portions of each sheaf meet with concussion, while in the swathe almost every ear encounters a hard stroke from the reel-board, the platform, or projections on the belts or chains. The screw platform of Burgess and Key's old machine was comparatively free from this objection; Hornsby's swathing machine worked very well until the crop proved too much for the dividing iron; and the machines of the Beverley Company hardly proved equal to the difficult task before them. These reapers possess peculiar facilities; the horses, walking behind, can charge into the midst of a standing crop without any previous opening of a path by the scythe, and the swathe may be delivered to right or left; and, as there is no 'side draught,' the three-horse machine can take an eight-feet width of cut, mowing a much larger acreage per day than is attainable by any other reaper. The framing, the position of the platform, and details of the working parts, have been lately much improved.

"Fourteen grass mowers were tested upon a piece of thin, weedy meadow, laid flat by rain, and with a difficult bottom for the cutters to travel over. In Barber's Eagle mower you can lift either end of the finger-bar to pass over an obstruction. In Samuelson's mower you raise the finger-bar and set the wheelwork in or out of gear—all by means of your foot. In Child's

American 'clipper' the draught-iron from the whipple-trees is made to relieve the finger-bar of its downward pressure upon the ground, and by a lever you can give the cutters more or less pitch, without stopping the horses. In Hornsby's mower the finger-bar is at liberty not only to rise and fall of its own accord at either end, but also to twist as it were, so that the cutters always creep close to the ground, the 'pitch' being self-regulated by a small castor-wheel travelling in advance. In Kearsley's mower the whole frame accommodates itself in this manner to inequalities of surface, gauged by a larger castor-wheel travelling in front, and the framework is of wrought iron. Burgess and Key's new mower packs all the mechanism in a wonderfully small space between the finger-bar and one of the main driving wheels, over the track cleared by the last course of the machine; and thus the crank-shaft can be placed close to the ground, bringing it on a level with the cutters, reducing the friction in work, and shortening and strengthening the connecting-rod.

"Between Thursday morning and Saturday night nine general-purpose drills, fifteen corn-drills, fourteen small-occupation corn-drills, two hill-side delivery-drills, fourteen turnip-drills on the flat, eight turnip-drills on the ridge, five drills for small seeds, four drill-pressers, eight dry-manure distributors, three liquid-manure drills, five liquid-manure distributors, and nine horse-hoes on the flat, were subjected to actual trial. The drills were worked in turn with the requisite varieties of seeds and manures, the construction and mechanical details examined, and selected drills made to deposit upon hard road, where the regularity of distribution could be seen, as well worked for some time with the coulters in pulverized soil. Hornsby's arrangement of the manure barrel in the common drill is an effective improvement. Coultas has introduced many simple but valuable details into his first-class drills for all purposes, more particularly the copper 'tins' for artificial manure. Reeves has furnished his liquid-manure drill with a cylinder that prevents the cups from breaking; and Sainty has brought out a novelty in the shape of springs instead of weights upon the drill levers, an invention that lightens the implement, and adds to its efficiency where level and well-pulverized seed-beds are to be sown. In dry-manure distributors, *little advance has* been made upon Chambers's barrel, with scrapers for sowing either minute or considerable quantities per acre. Priest and Woolnough's horse-hoe now competes against the novel implement of Sainty, with the spring levers and light lifting frame supplanting the old chains and winding barrel, and Hornsby brings out a horse-hoe having a swing steerage operating with spring hangers in an exact and easy manner. These weeding implements were tried upon young growing rye, and again upon a turnip crop.

"Amongst the heavier class of machinery we noticed Aveling and Porter's eight-horse power locomotives, which travelled from Rochester, hauling another engine and a couple of heavy trucks along the turnpike roads at the rate of about fifty miles a-day. John Fowler & Co. exhibit a ten-horse power single cylinder engine, fitted for traction purposes and stationary driving only, without the cultivating gear. This engine demonstrated clearly by various experiments its great power and remarkable facilities at different speeds and varying loads upon all sorts of curves and gradients. The Leeds Steam-plough Works exhibit here, in operation, both the single and double engine system of steam culture. Messrs Howard, of Bedford, show the adaptability of their new traction-engine for working upon hill-sides, the boiler being placed crosswise upon the carriage frame, and thus preserving the water-level."

113. *Traction, and other Engines, on Common Roads.*—"The applicability of steam to common roads is a problem of great importance, but one that, as yet, has been only partially solved. Railways have rendered us dissatisfied with old-fashioned modes of conveyance; and although vast sums have been expended on more than 20,000 miles of turnpike road in England and Wales, these splendid monuments of energy and skill would seem likely, in future, to be of comparatively but little use. Yet, in their day, they gave a great impulse to the progress of civilization, and contributed immensely to the comfort and convenience of the public; affording a facility of communication between distant places that contrasted very strikingly with what alone was possible with the miserable roads of an earlier period. They superseded the bridle paths and narrow lanes by which, in former times, the country was sparingly intersected; but, in their turn, *they have* been superseded by railways. The latter have, how-

ever, their disadvantages. On common roads extortion was kept down by the danger of successful competition; with railways there is no wholesome fear of such retribution; their monopoly is so certain that they fear no rivals; and hence railway companies, knowing how much the public is at their mercy, do far less than they ought for the accommodation or the comfort of the traveller. But this is a narrow-minded policy. At present people travel as little as they can; under a better system they would travel as much as they could: in the one case, travelling is an annoyance that is dreaded; in the other it would be a pleasure, to be enjoyed as often as possible. But abuses, in the long run, suggest their own correctives, and parliamentary interference may at length become necessary. There is one remedy, however, which might be found more or less effective—the utilization of common roads, by using them for steam carriages. In some rare cases the best mode of doing this would be by rails or tramways; but in most, these would be too expensive, or would interfere with the ordinary traffic of the road. Traction engines, steam omnibuses, &c., of an unexceptional kind, would answer the purpose in most instances. These have as yet, however, scarcely attained that perfection of detail, or that economy of construction and maintenance which would suggest their general adoption. Yet coal affords, unquestionably, a cheaper motive power than hay or oats; and the general use of good traction-engines, &c., on common roads, would lessen the over-traffic by which railways are oppressed, and in meeting which the public safety is imperilled. They are, indeed, open to objections, which seem to have great weight. On ordinary roads they would require the most unceasing vigilance, or frequent collisions would take place. But it may be replied that a very nearly equal care is requisite on the part of those who drive omnibuses and other vehicles drawn by horses. And, as a compensation for any extra attention required by steam-horses, it should be borne in mind that they are thoroughly docile and obedient, never run away, and when required to stop, will do so in the shortest time compatible with their getting rid of the motion which urges them onward.

"It is supposed that traction steam-engines on common roads *would frighten horses*; but time would soon cure this evil, as it has done in the case of the railways, which often pass very near crowded thoroughfares, in full view of horses who, being more or less accustomed to them, take little or no notice of them. The steam carriage is said to injure the road; but its broad wheels—and there is no good reason why they should not be broad—will, on the contrary, do good service. It is true that the great difficulty with traction-engines, &c., is the obtaining a sufficient hold on the road, so as to prevent the wheels from revolving without progression, and that this is effected by protuberances which sink into the road. But any slight injury that may be caused in this way is far less than what arises from the horses' feet, in their endeavour to obtain that hold of the road which is necessary also to them, to enable them to progress even with ordinary loads.

"Strenuous efforts have been made at various times to introduce steam on common roads, and exceedingly ingenious contrivances have been used for the purpose. But in most, if not in all cases, that very ingenuity—resulting in complexity and lightness little suited to the rude shocks to which heavy vehicles on common roads are inevitably exposed—rendered the cost of construction and repairs inadmissible in a commercial point of view, even when the experiments were in other respects entirely successful. Hancock, Gurney, and others, although their persevering efforts were not sufficient to save their projects from failure, have added to our stores of mechanical and constructive science.

"If the time is not yet come for the application of steam to the general traffic on common roads, there are certain circumstances in which it has already been found not only a convenience, but a necessity; thus, in dockyards, large factories, &c. At first, even in these cases, the experiments were not attended with very encouraging results. In steam carriages and steam omnibuses simplicity has been almost always lost sight of; and this mistake was made even with traction-engines. In attempting too much, they failed to do as much, therefore, as they might. It was not enough that they were capable of locomotion on good roads; it was sought to make them suited to travelling through miserable lanes and bye-roads, and even over morasses; and in many instances they were expected at the same time to be capable of driving machinery, extinguishing fires, &c. Endless railways and other complicated contrivances were therefore attached to them, and their real capabilities were in a great degree overlooked, in the desire to make them possess powers that were comparatively unimportant.

"Traction and other steam engines on common roads are exposed to certain great and peculiar inconveniences; among these, not the least is the necessity of stoppages for a supply of water and fuel. But such delays, and the diminished speed in ascending hills, &c., must be compensated for by a good use of the better portions of the road, and only a fair *average* velocity must be looked for.

"The concussions to which steam engines on common roads are exposed—an evil increased by their necessarily considerable weight—render solidity and simplicity essential to their success. While, at the same time, the loads they are capable of drawing are limited by the amount of adhesion between the driving-wheels and the road.

"Steam locomotion on common roads has made but slow progress. Nearly one hundred years ago, Cugnot proved, by a machine which still exists, that steam locomotion on ordinary roads was possible. Locomotives were not used on railways until 1804; and yet locomotives have far outstripped road engines in the race. The latter are still struggling; the former have come into general use. Engines for common roads have not, however, at any period been forgotten. From time to time, enthusiastic experimentalists have taxed their brains and dissipated their means in attempts to bring them to perfection. Occasionally, even, success seemed to have been achieved. Hancock's omnibuses ran regularly for some time between Paddington and the City; but, in the end, the railway locomotive extinguished its competitor. In old times, the velocity possible to steam-engines on common roads might have abundantly satisfied the public; but now the mails and passengers require, as a rule, a speed that would be out of the question on common roads. Hence, perhaps, the slow progress of road engines; they are not so important as they would have been at an earlier period, and, therefore, ingenious men have not given them the attention which is necessary to bring them to the perfection of which they are undoubtedly *capable*. *Yet* railways, though they have lessened, have not done away with the necessity for a good use of ordinary roads, which penetrate the country in every direction, and extend into nooks and corners into which railways will, perhaps, never venture. Above all, the common roads would be found very convenient for short distances, and for transit to railway stations.

"There is no reason why traction-engines, &c., should not come into ordinary use. Steam is certainly in many respects more convenient than horse-power, and ought to be more economical. A great obstacle to the more general introduction of traction engines is due to the opposition they encounter from those who have control over the roads, and, above all, to the order recently issued by the Home Secretary, that they should not travel on common roads, except in the night time—an order tantamount to a prohibition of the use of steam-engines for agricultural purposes. This appears the more unreasonable, as Government has distinctly recognised the value of traction-engines in its dockyards. The passage of steam-engines along public roads by night, must be attended with a danger which has not been found to exist by day. Their noise and smoke are, no doubt, objectionable; but these are not inseparable from them. The great inconvenience and even injustice of their prohibition, was shown very clearly by a deputation to Sir George Grey, on the 10th of February. If, generally speaking, traction engines, &c., are too wide, and take up too much space, it might easily be remedied. Unreasonable opposition is an impediment to the progress of improvement; but no great change, however advantageous, has ever entirely escaped it."—*From an article in the "Scientific Review."*

114. *The New Traction Engine Act.*—"There are many directions in which the work of a mechanical innovator in this country is the work of a traveller or settler in an Indian jungle, or in the backwoods of the Far West. Before he can make much progress, he has to cut down a whole forest of obstructiveness; and his time and energies are often exhausted by futile endeavours in clearing away the mediæval rubbish of prejudice. A task of this kind has been for more than thirty years the lot of workers in the application of steam to common roads; and, metaphorically, the bones of a previous generation of inventors whiten the track of this direction for mechanical enterprise. Apart from the usual difficulties attendant on any innovation,

the traction engine has had to overcome two main impediments in this country. Local opposition and prejudice have taken the concrete form of impossible tolls in the highway; and the well-meant interference of legislation has been greatly marred by want of engineering knowledge on the part of the legislators.

"With respect to the tolls charged previous to the Locomotive Act, 1861, Mr. Gurney stated, in 1831, before the House of Commons, that, for instance, on the Liverpool and Prescot road his steam carriage would be charged £2 8s. against 6s. for a stage coach; £1 7s. 1d. on the Bathgate road; and £2 on the Ashburton and Totnes road, while a stage coach would, at both places, have had only to pay 5s. These tolls were rendered more reasonable by the Locomotive Act of 1861, which, while doing a certain amount of good, is, on the other hand, by no means free from deficiencies. The great and increasing importance of steam transit on common roads is now beginning to be more understood; and having received a fresh impulsion by the application of steam to ploughing and agriculture generally, a revision of the law has been long called for from many quarters, and, amongst others, by ourselves. Mr. Holland, M.P., well-known to scientific agriculturalists, seconded by Sir Edward Dering, M.P, and Sir John D. Hay, M.P., has accordingly introduced a fresh bill for the purpose, and it has been already read twice in the House.

"The new Act first of all proposes to repeal the fifth, ninth, and eleventh clauses of the Locomotive Act of 1861. The abolition of the fifth clause of this Act, by taking away the power of the Secretary of State to prohibit the use of any traction engine causing 'excessive wear and tear of the highways,' or supposed to be 'dangerous to the public,' must be a great boon. It will do away with the arbitrary and intermittent interference of the Home-office, which has been often called for by prejudiced local cliques. Instead of the ninth clause of the old Act—requiring two persons to every engine, and a third if the engine be dragging more than two waggons—at least three persons have to be employed for the engine, besides the man attending to the waggons. This third man has to 'precede the engine by not less than sixty *yards,' and* the engine has to be stopped or worked to *his signalling.* *Any* steam whistling, or opening the mud cocks, or blowing-off at the safety valves is prohibited while on the road; and the engine must be stopped if required by anybody managing a horse in the neighbourhood of the engine. Nothing is said about any lights to be used at night. The limit of speed, according to the 1861 Act, is ten miles an hour on a turnpike road, and five miles an hour in passing through the streets of a town or village. This is limited by Mr. Holland's bill to four miles an hour and two miles an hour respectively. At present, 'no locomotive shall exceed 7 ft. in width, or 12 tons in weight,' except by special leave from the municipal or other authorities of the district where it is intended to be worked. These limits are to be increased to 9 ft. width, and 14 tons weight, but the tires of the wheels are to be proportioned as previously. As will be remembered, the minimum breadth is fixed at 3 in. for any traction engine, 'not drawing any carriage,' the width having to be increased 1 in. for every additional ton, or fraction of a ton; while every traction engine 'drawing any waggon or carriage, shall have the tires not less than 9 in. in width.' The wheels must also 'be cylindrical, and smooth soled, or used with shoes, or other bearing surfaces, of a width not less than 9 in.'

"The feeling, after perusing this bill, is that of a sort of thankfulness for small mercies. Its framers are evidently firm believers in the proverbial '*chi va piano, va sano et lontano*,' and apply it to both the engines and the enactments regulating their use. However, we do not object to the limitation of speed. In the meantime the horses will become educated to the steam engine, and the speed may then be increased. At any rate it will put a stop to amateurs rushing wildly through the country on traction engines—frightening good people out of their wits—and retarding their application to useful purposes. In the next place, by taking away the power of the local authorities for undue interference, it will undoubtedly do much good. The state of things is now more equalised, and local impediments are smoothed down by the legislative garden roller. But the bill has some of the shortcomings of its predecessors, and it shows distinct traces of a want of technical knowledge. It still requires smooth wheels, limiting the width of the tires to nine inches.

"These requirements, and especially the first, are of course intended to meet the danger of injury to the road. Now its framers would doubtless be surprised when we tell them the requirement of a smooth surface just tends to defeat their purpose. As long as a wheel does not slip, it is more likely to do good than harm to the macadamised surface; but as soon as it slips, the wheel then acts as a sort of portable grindstone, literally grinding up the metal of the road at particular places. We do not by any means propose that spikes or spades should be used on the periphery of the wheels; but there is a mechanical golden mean between the portable grindstone and the portable digger. A number of hemispherical steel studs spread over the surface of the tyre, and jutting out from half-an-inch to three-quarters, would commonly prevent slipping, on the one hand, and as often the use of paddles, on the other.

"The fact is, that we would strongly advise Mr. Holland to take scientific evidence, not merely upon the mechanical points of modern traction engines, but on the whole question as to their use. It is not improbable that, with the same weight of traffic, the road would be injured much more by the hoofs of the horses than by the wheels, smooth or spiked, of the steam cart-horse. There is another question of enormous importance: How far may it be expected to serve instead of the expensive feeders of main lines of railways? There is now more than one member of the House who owes much of his wealth and position to his having promoted the formation of needless 'feeders' of lines of railway —feeders which have acted with a strong force of suction on the pockets of the unfortunate original shareholders. We should say that one of these men would be louder than anybody else if his team of thoroughbreds happened to start at a gust of steam from the exhaust pipe of a traction engine."—*Engineer.*

115. *On the Application of Machinery to Agriculture—Some Points Affecting its Future.*—From a series of articles by R. Scott Burn in the "Scientific Review," under the above title, we take the following: "The most economical way to apply the *power of steam to the culture of the soil*, whether that be effected by the aid of the plough or the grubber, or by the rotatory cultivator, is another of the problems which await a successful solution. Possibly some of our readers may think that the solution has already been given; but while admitting that a solution *of one point has* been fairly obtained, we are far from thinking

that this is the case with the whole of the points involved in the problem. Thus, while admitting that it has been proved that steam *can* be applied to cultivate the soil, we cannot admit that it has, as a rule, shown itself capable of being applied economically. A vast deal has yet to be done before we can make a steam cultivating machine as widely and as easily applicable as the horse-dragged plough or the grubber; and until these points are reached, it can scarcely be said that steam has accomplished its mission. Its successful adaptation to large and isolated farms is, no doubt, peculiarly gratifying, and proves what can be done by its aid; but its full power will only be witnessed when it can be easily carried out as a part of ordinary farm labour in all localities. And it is to aid in this wide extension that the attention of our mechanicians and farmers must be given. But we confess to seeing greater difficulties in the way of fields being presented in the condition best fitted to aid the application of steam to their culture, than in the mechanical realization of plans fitted to carry it out. We have unbounded faith in the mechanical abilities of our engineers, so that, sooner or later, we shall have mechanism adapted to cultivate the smallest holdings; but we have not an equal faith in the likelihood of proprietors of land doing what we conceive should necessarily be done before steam cultivating mechanism can receive its fullest development. So long as farmers continue to look upon the work to be done in connexion with steam culture as being alone within the province of the engineer, so long will its successful realisation be retarded. Farmers and proprietors of land have much to do to aid in this, and how they can aid we have had occasion more than once to point out; and if again we do so, we trust our readers will pardon us, not because the views we entertain are mere crotchets of our own, but because we do consider that they have an important bearing upon the future prospects of steam cultivation. The new power, then, brings into existence a new condition of circumstances, which must be attended to if the full development of that power is desiderated. Machinery, to be used most economically, must be used as continuously as possible; the more breaks and interruptions there are in its working, the lower the per-centage of profits. This not only demands that the machine we work with shall be so strong and well-proportioned that, once set to work, it shall go on working for the maximum of time with the minimum of breakages and repairs—to secure this is the task of the engineer—but there is another essential element of success, and that is, that the material upon which the machine is to operate be presented to it in the condition best fitted for the exercise of its powers—to secure this is the task of the party using the machine. This may involve certain preliminary operations: in the application of steam power to the culture of land, we maintain that these operations are essential. We maintain, further, that these operations are the work of the proprietor or farmer of the land. What these are can only be briefly alluded to here—namely, the enlargement of fields, by taking in a number of small fields; the getting rid of huge fences and wide ditches, the levelling of land, and the removal of huge boulders from the soil. These two positions here stated are axiomatic in all cases where the application of machinery is concerned, and they are as applicable to farming as to any other branch of business. If neglected, loss and disappointment will follow, just as we have seen that they have followed in more instances than one. When the farmer fulfils his conditions as well as the engineer has fulfilled his, we shall have, in the application of steam to the culture of land, fewer of those annoying breakages and stoppages, with which, in the history of the progress of the art up to this date, we have been too familiar. The economical application of steam to the cultivation of the soils of our small farms is thus one of the problems yet to be solved; and its importance may be estimated from the fact that large fields and farms where steam culture can be most successfully carried out are the exception, small ones the rule. But the problems connected with the future of steam culture are not yet exhausted.

"An important element in the discussion of the points connected with Agricultural mechanism is that which has reference to the kind of work done by it, and whether it is that which we require. Another not less important element is the consideration as to whether, having got a machine to do one kind of work, it is all the kind of work it can do, and all that we require. As a rule, more and better work will be obtained in agricultural operations *by having them done* by one part at a time, and that part done by one implement. But when we bring to our aid the power of steam, we bring such an expansive and generally applicable power, that we can yoke it to a many-sided purpose. We have seen what we can make it do in the barn and the fold, and from that we may predicate safely that we do not exhaust its powers when we make it do one work only in our fields, and that work ploughing. *Ploughing does not exhaust the labours of the field.* We have to sow our seed, cover it in, hoe and weed the growing crops, reap them when they are ripe, and cart their produce from off our fields. Can steam help us in none of these things? Truly, he knows little of its adaptability who thinks it cannot. But there must be an adaptability of circumstances between the work to be done and the power which is to do it. Steam has its peculiarities, and these must be attended to before we can command its powers. One of these is the continuity with which it gives out its force; and this economical feature is connected with it—the longer we can keep it at work the cheaper can we get that work done. We work steam, therefore, to but a fraction of its power in the field when we make it plough only—making elaborate preparations for that process, which preparations are valueless after the primary work of culture is performed. It is—to borrow an illustration from the book trade—like setting up types for one edition only of a work, and then distributing the types; whereas, by stereotyping them, we can reprint the work at a mere trifle of the cost. This points at once to some means of making our preparations for ploughing our fields permanent, so that we have not always the work of preparation to do each time we cultivate them. Leaving for after consideration the question whether this permanent preparation would pay for ploughing alone, it is evident that a point is offered to us in connection with it of immense importance—namely, will the preparation we make for ploughing enable us to do other work of the field by the aid of steam? If so, it is quite clear that we bring in another element which will greatly reduce the cost of the application of steam to the cultivation of our farms, using this in a more extended sense than involving preparation of the *soil* merely. This extended application of the power of steam, then, is another problem which awaits the solution of our machinists. As yet, but the outer hem, so to speak, of the subject has been taken up;

we doubt not its fuller investigation will lead to some practically useful results. But this very preparation of the soil for the working of our steam-cultivating machinery involves a use for it in a direction to which much attention has not been given, but which, nevertheless, is one of vast importance—namely, the *moving of soils* from one part of a farm or a field to another, so as to bring the whole to as level a surface as possible; and, further, the *mixing of soils*. We can but simply allude to these two points; but much might be said on both of them did space permit. Suffice it to say, that in the mixing of soils so that we can take from the redundancy of good, fertile soil of one part, and transport it to and mix it with defective or sterile soil of another part, lies a future of utility which has somehow been strangely overlooked. To aid in this transmission of the fertile wealth of soil of one district to the sterile deficiency of another, the extension of agricultural lines of railways will be of immense service. In this direction alone much has yet to be done by the engineer.

"In close connection with the subject of steam culture is obviously the improvement of *steam-engine mechanism*. Although we have every reason to be proud of what the steam-engine has done, we are fully convinced that we have not yet come near the *ultimatum* of its power. We have yet, we believe, to see a remarkable development, and in the direction of great power compressed within little space. In boilers, too, we have still to see vast improvements. Man has not yet the mastery over this powerful servant of his; hence do we read so often of such frightful accidents taking place through its means. Boiler engineering is in its infancy, and with greater economy we shall have yet greater safety: economy in the consumption of coal by improved furnaces or modes of firing, safety in raising and storing up of steam in improved boilers. These points involve subjects of the greatest importance to the future of agriculture, and will test severely the capabilities of our engineers. Other problems awaiting solution are the best modes of *reaping, housing, and preserving grain*. These are of the highest importance, and have not yet met with the attention they deserve."

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